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PREFACE

Through the years, the Southern Pasture and Forage Crop Improvement Conference (SPFCIC) has come to be regarded as the nation's best regional forage conference, and the 44th certainly did not tarnish that image. Credit for its overwhelming success must be attributed to many people, but we must be especially grateful to the local planning committee, to the program chairs, and to those who presented papers. It is impossible to measure the impact of a conference such as this, but it unquestionably is immense. Hopefully, through these proceedings, the 44th SPFCIC will continue to benefit forage scientists for years to come.

These proceedings include the papers and reports presented at the 44th meeting of the Southern Pasture and Forage Crop Improvement Conference (SPFCIC) held May 10-12, 1988 in Lexington, Kentucky, with the University of Kentucky as host. Papers presented in those sessions appear on the following pages.

Minutes of business meetings of the Executive Committee and the respective work groups are also included in the 44th Proceedings.

Don Ball
Chairman, 44th SPFCIC

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THE ROLE OF COOPERATIVE AND COLLABORATIVE RESEARCH IN FORAGES

COOPERATIVE (INTERDEPARTMENTAL) RESEARCH: PROS AND CONS[1]

J.C. Burns, D. S. Fisher, and K. R. Pond[2]

INTRODUCTION

The terms cooperative or team research, as well as interdepartmental, multidisciplinary or joint research, are frequently used interchangeably, inferring that two or more individuals are working together with shared research objectives. These individuals generally provide different expertise (disciplines) permitting additional dimensions of a particular problem to be studied. The wisdom of interdepartmental research is that results may be more encompassing thereby achieving greater knowledge with an increased efficiency.

Cooperative research involves a dynamic matrix of scientific and technical personnel that generate intentions, commitments, and expectations in both researchers and administrators. The same matrix includes facilities and the source and quantity of funding necessary to drive the total effort. This matrix is in constant flux because of individual differences, shifts in funding and constant changes that occur in federal and state regulations. The aspects of intention and commitment in cooperative research and the subsequent advantages and disadvantages of such cooperation are discussed.

THE INTENTION

Scientist

The first step in the formation of cooperative research generally resides, and properly so, with scientists sharing ideas and developing an image of what might be achieved through cooperation. Following discussions (generally several over time) intentions develop and are shared regarding future cooperation on a specific objective. Such intentions imply only what each individual has in mind to do or to bring about as a result of his/her involvement. Further discussions may ensue which reaffirm the previous intentions and usually generate even greater interest. At this point no commitment may be intended or felt by any discussant. However, intention levels have been generated and the potential cooperators must begin discernment between intention and potential commitment. Discernment is an individual process involving intuition or may only amount to a guess. This interest category of intention seems best represented by the designation "cooperator" on many research proposals.

Administration

In most situations involving cooperative research, assistance from the administration at the work unit or departmental level is essential. Occasionally, involvement of the administration at a higher level is required. Administrative involvement is needed if the magnitude of the cooperative effort requires additional funding, realignment of or addition of facilities. Another area involves relaxing of the operational policies among the cooperator's unit (such as a work unit within the federal system or a department within the state system) so work can be done with minimal effort. Rigorous unit policies can be exhaustive when encountered daily.

Enthusiasm and encouragement from the administration for interdepartmental research is generally forthcoming and the intention to assist with such problems generally conveyed. Such intentions again imply little more than what the administration might do to enhance the general process. This encouragement should be taken as such, but is frequently misinterpreted by scientists as commitment. This is clearly an erroneous assumption, and the result of optimistic and enthusiastic minds oriented toward research achievement. Generally, no effort is made to clarify intention vs. commitment, as both researchers and administrators would rather allow the truth to remain in the gray area.

THE COMMITMENT

The heart of continuous, fruitful cooperative research resides in the commitment of both the cooperators and administrators to achieve the identified objectives. Commitment infers an agreement (or pledge) to contribute as appropriate to the success of the total effort. This is a step beyond "good intentions" as an obligation has been accepted. The obligation binds one to a specific course of action, but without tangible penalties for nonfulfillment. Ultimately, the penalty is incomplete data leaving the team short of their objectives and the reneging individual labeled as a poor cooperator.

The status of a cooperator with commitment is generally categorized on many research projects as a co-leader. It implies a contribution of the cooperator's time, funds, technical sup-

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port, or facilities either singly or in all combinations to achieve the objectives of the research.

THE EXPECTATION

Expectation is the perception that an event has a reasonable probability of occurring. Expectations are essential in sustaining cooperative research, but are different for scientists and administrators.

Scientist

Expectations that a scientist forms when entering cooperative studies begin early during initial discussions and become clearer as discussions continue. Expectations are initially based on the opportunity to achieve knowledge and insight which is less possible through independent research. During the course of cooperative research, there is a gradual shift, probably unintentional, in expectations. The initial drive to acquire new knowledge becomes secondary to reward expectations which include publication opportunity, program enhancement, monetary compensation and peer recognition. This array of expectations will develop regardless of the individual's degree of involvement (i.e., intentions or commitment) in the project. A contributing member with intention, but without commitment, will usually find his/-her expectations frustrated. Unfortunately, intentions generally result in minor, if any, contribution thus subsequent recognition is usually nonexistent. At the same time, expectations can be sufficiently high that even the committed person (i.e., one making appreciable contribution) can experience frustration even though recognition was reasonable and shared by the total team. In this case, recognition received did not meet the level of expectation. This must be guarded against by communication among scientists and administrators in maintaining continuing cooperative projects.

Administration

The concept of cooperative or team research appears widely accepted and desirable among administrators with some feeling that in certain areas it is essential. This has probably resulted from the realization by scientists and administrators that much of the knowledge to be gained in biology (plants or animals) resides in studying interactions. The effective study of many biological systems results in complex experiments that require expertise from several disciplines and/or research projects.

Surprisingly, many administrators admit to not having any formula to initiate or sustain activity in cooperative studies. The tendency is to remain insulated as much as possible from the practical aspects of the process, but present it as part of the unit's program when viewed from the outside. An administrator's expectation from cooperative studies is that he will be recognized by peers, and upper administration, as a talented and successful leader.

In this case the expectation is based on the process and not the value or accomplishments of the research effort. Consequently, administrator's expectations from cooperative research are probably met more often than are scientist's.

THE REALITY

The conduct on a daily basis of interdepartmental research, by necessity, involves association among a wide array of personalities. Attitudes, feelings and egos of individuals ranging from secretarial to technical to scientific all operate within the confines of the available facilities at the existing level of funding. These interactions vary widely from project to project both within and among work units. Furthermore, each cooperative project generally resides within a unit much larger than the cooperating team. In addition, individuals who compose the team are frequently from units or departments composed of many individuals who directly impact the success of the team without direct contribution. Variables operating inside and outside the cooperative project lead to a number of advantages and disadvantages that can be generalized to cover most cooperative or team research efforts. These are listed below and discussed as pros and cons of interdepartmental research. It should be noted that not all points are intended to apply to every research effort, but many can be identified as applying to most cooperative research ventures.

Pros of Interdepartmental Research

1) Focus of More Scientific Expertise.
Scientists from several disciplines can bring more scientific expertise together to delineate the problems and the appropriate methodology to arrive at the measurements required to meet the research objectives.

2) Study Multiple Factors.
Joint effort permits consideration of more factors that have potential bearing on the research objectives. In individual research, factors known to impact the research objectives may lie outside of the expertise of the scientist, and are frequently ignored or held constant. Team research permits such factors to be studied.

3) Detailed Measurements.
Each cooperator has responsibility for his/her area of interest. This concentration permits detailed measurements to adequately characterize the changes in the factor(s) that have a bearing on the response(s) of interest.

4) Common Experimental Units.
Measurements on or relative to the same experimental unit provide the opportunity to examine general associations of cause and effect response between or among a number of measures. Cost efficiency seems inherent in such studies

since creating a particular biological state occurs once for all measurements as opposed to recreating (if possible) the state if measurements were taken independently. This efficiency may not always exist because more expense may be involved in personnel, equipment or facilities to obtain all measurements simultaneously. It is possible that part of the measurements may never be obtained if left for separate experiments. Knowledge obtained in the latter case would not be as complete or as beneficial as when all measurements are taken simultaneously.

5) Potential for Major Research Advancement.
The proper mix of skilled scientists in a research setting increases through observation, measurements and integration, the probability of obtaining new and important information that will advance understanding of the processes being studied.

6) Continuous vs Discrete Data.
Frequently individual studies will be fragmented because of the number of factors that must be measured and the frequency that measurements may be required. With sufficient scientific, technical, and instrumentation capability, frequent measurements permit trend-type analyses resulting in a descriptive relationship as opposed to a selected number of discrete samplings which are difficult or impossible to integrate or relate.

7) Recognition
Recognized by peers as a member of a research team involved in pioneering work can be extremely rewarding. The work being published is seen as a step or two removed from traditional data that dominate some present day journals. Both personal satisfaction and monetary benefits can occur. Recognition may include invited presentations, awards, and local respect within the work unit or department.

Cons of Interdepartmental Research

1) Increased Cost
The number of factors measured and the detailed measurements (physical, chemical and biological) generally require an increase in personnel (technical and support), instrumentation, physical facilities and operational funding. This increase may not be forthcoming because the administration's intentions did not move to commitment. Consequently, the research effort is soon underfunded, the cooperators become discouraged, and fulfillment of the objectives remain incomplete.

2) Scope Expanded and Efforts Diluted.
As a member of a team, each scientist becomes exposed to the other disciplines. The interaction of factors among the disciplines draws the attention of all the scientists and they begin to integrate the various responses. The tendency is to shift from a narrow approach frequently followed by an expert, to a wider view taken by a generalist. Focused efforts are diluted by time commitment to the team. In personal research an individual can make major decisions on the spur of a moment and move forward. In team research many decisions require discussion. Schedules and rescheduling for joint meetings and subsequent discussions to arrive at decisions, although necessary, can be extremely time consuming and exhausting.

3) Personality Conflicts.
The opportunity for personality conflicts are greater and results far more damaging when individuals work in close proximity and the work conducted by one affects the work of another. Some individuals can handle changing situations and work through problems in a consistent and reasonable manner. Other people react in extreme ways to stress, or to other people, and can keep a research team in turmoil. Clearly, not all people are emotionally or mentally suited for cooperative research. Many times individuals want to be a part of a team but fail to realize their limitations. A small amount of unrest can nullify major efforts to maintain a smooth cooperative relationship.

4) Proper Representation.
The concept of cooperative or team research places all individuals as subservient to the team. However, in most research structures such a team would lack administrative support and lose funding. Most successful teams have a spokesperson who promotes the team at the right times and in the right places to keep the team's activity in the forefront. This may require a spokesperson in each team members' work unit and is especially important in systems using zero base budgeting.

5) High Risk.
Cooperative research has a high risk component because of the fragile nature of the research arrangement. Productive cooperative research functions in much the same way as does negotiation.

Negotiation continues and is successful if both sides believe they are winners. If one side is losing, negotiations cease. In cooperative research, all individuals must benefit personally and professionally or the arrangement will fail. One scientist is not likely to serve another. Since there may not be tangible penalties for nonfulfillment, there are no legal levers to cause continued involvement.

Another aspect adding to the risk factor is the difficulty in discerning between intention and commitment. Not all team members will be committed to the same degree and some enter cooperative studies as if committed, but really only have intentions. Such individuals fail to pull their weight and are unlikely to contribute as they agreed. Although not always evident, there is general apprehension between scientists and the administration. Scientists resent being directed but look toward administration for leadership. Administration frequently fails the leadership role by leading

only with words and intentions and remaining uncommitted. "Hot topics" can draw the administration's attention while a research team needs stability and commitment for quality scientific efforts.

6) Inadequate Recognition.
The difficulty in providing fair recognition to members of a productive team may be the biggest negative factor in cooperative research. The complexity of cooperation exceeds that encountered by the independent researcher. In the first place, the daily conduct of work in a team setting, especially when team members are housed in different locations (units, departments, or geographic regions),is more complicated. Secondly, the nature of the research and the interactions examined may make the data more difficult to interpret. Yet, the independent scientist who focuses on a specific (narrow) problem and researches the area in depth, can quickly (6 to 8 years) become an "expert" with surprising national and international recognition. This requires that the individual be well-published and participate in regional and national meetings. Such a person will most likely move quickly through the promotion levels in either the federal or state systems. Such advancement may exceed that of a team researcher, but does not necessarily indicate a more accomplished scientist. This is partially associated with a noted advantage in most promotion systems for single or senior authored publications. Being listed as the fourth author of a team research paper may not greatly help one's score in many evaluation systems. Yet, cooperative research requires that authorship be rotated so, in fact, the last author of some papers may have made as much or perhaps even a more significant contribution to the results than did the senior author. The designation of a team leader further complicates this process. Evaluation of authorship needs to be better understood when scoring individuals involved in cooperative research.

A solution to the problem of senior authorship in promotion and which is generally favored by administrators, is to maintain in addition to the cooperative research, a personal research program. While this can benefit the establishment and development of a scientist in his/her discipline and ultimately the team, the concept coming from the administrative level reflects negatively on cooperative research and will likely be reflected in subsequent peer evaluations. Furthermore, it places an unfair burden on the individual participating in cooperative research. In such situations, personal research competes strongly with the cooperative effort for time and funds and hinders the fruitfulness of cooperative research. Another approach is to encourage scientists to publish their segment of a joint project prior to its integration into the team findings. This causes problems with co-authorship and unreasonable delays, creating frustration and loss of team interest. Further, prior publication will likely relegate publication of the team's findings to lesser vehicles such as final reports or local (regional, state) bulletins.

The reality is that scientists with the need to have his/her own program, reduces commitment to the cooperative project to a level of intention. While the expectations of administration are met by this solution, they fail to realize the detrimental effect on cooperative research.

Many research organizations rely on a "peer evaluation" system to initiate or determine promotion. Use of peer evaluation appeals to many administrators because it conveys the notion that people of equal knowledge, experience, etc. are making the evaluation. The fault in most peer evaluation systems is that the peer aspect is only relevant to the extent that all the evaluators are other scientists, or depending on the system, just colleagues (extension, teachers). Although exceptions do exist, few of the other scientists will be of the same discipline creating a problem of perspective. For example, scientists who are trained and function in a laboratory (plant or animal) or greenhouse setting have problems appreciating the need, difficulty and complexity of a five-year study with a perennial crop. Likewise, scientists who must conduct long-term studies have difficulty scoring short-term laboratory experiments.

Another aspect of team member recognition arises when the scientists are located in different units or different departments. Members of interdepartmental teams may be differentially promoted because the peer structure differs for each member of the team, and the philosophy for promotion can vary among units. Such differentials can become obstacles to interdepartmental research.

The peer evaluation concept permits minimal administrative input and takes away one of the management tools important to an administrator or supervisor in developing a sound, productive unit. This problem is somewhat alleviated in systems where the unit supervisor can present the scientist's case to the higher administration following peer evaluation. Also, discrepancies created by peer evaluation can be smoothed out somewhat in systems where annual evaluation and salary increases are determined mainly by the unit supervisor.

SUMMARY

Team research is a dynamic matrix involving the interaction of individual traits of scientific, technical and support personnel. These must be integrated into the capabilities of the research facilities. Special consideration needs to be given by all parties initiating cooperative research to separate intentions from commitment as cooperative teams are formed. Success in cooperative research can be extremely fulfilling and rewarding. However, problems

can and do arise and these should be considered carefully as they can have major consequences on people's careers. Most vulnerable to the pitfalls of cooperative research are young scientists striving to become established in their disciplines.

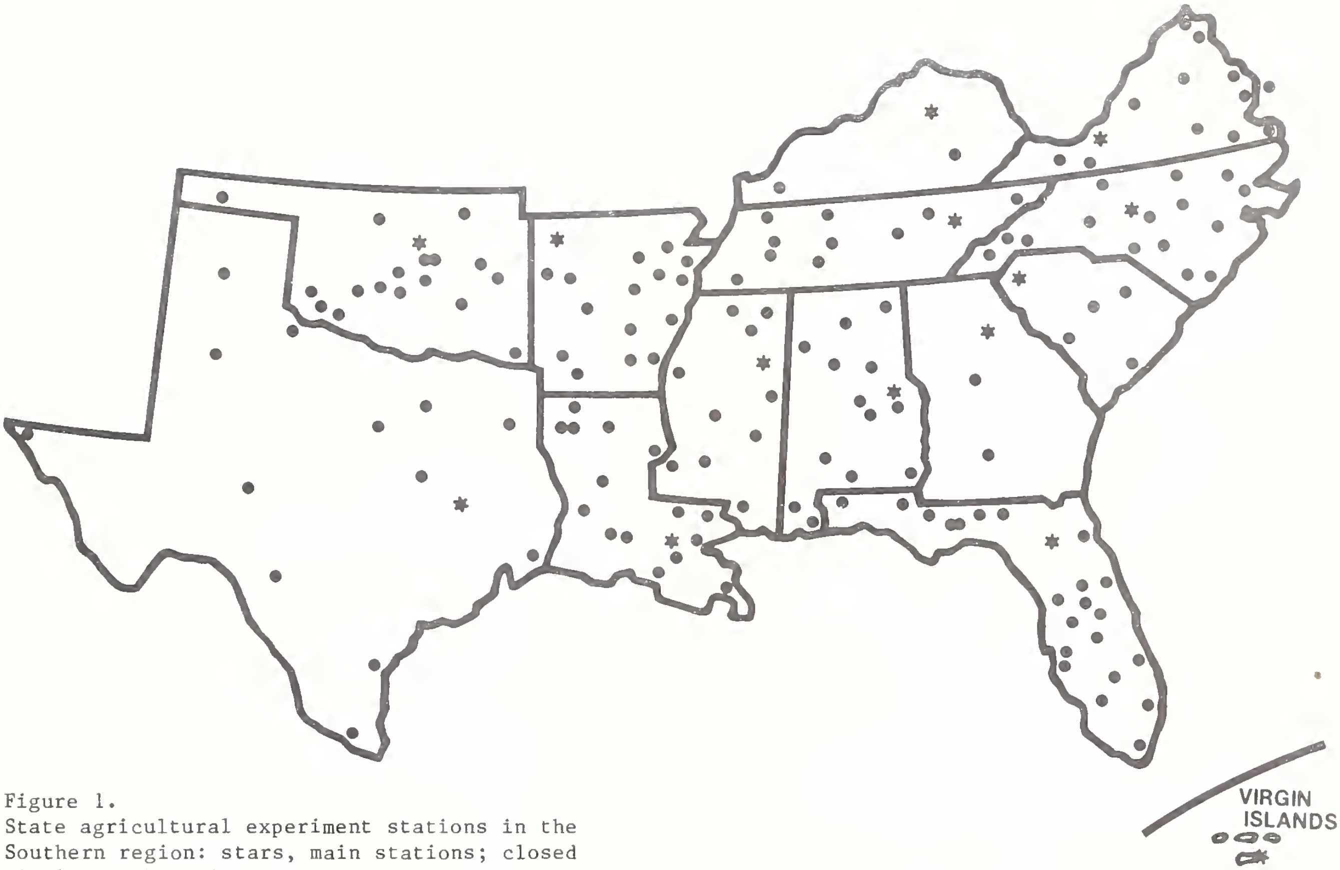

Figure 1.
State agricultural experiment stations in the Southern region: stars, main stations; closed circles, substations.

REGIONAL AND MULTISITE COOPERATIVE AND COLLABORATIVE RESEARCH

J.W. Holloway[1]

THE REASON FOR COOPERATIVE AND COLLABORATIVE RESEARCH

The most pervasive problems with agricultural research arise from the intrinsic nature of the research and are results of the goals of research. The goals are: (1) development of unifying theorems "tying together" observations previously thought to be unrelated, and (2) development of broadly applicable technology. The problems result from the fact that agriculture is performed on a shallow layer of the earth's crust characterized by discontinuities (topographical, political and physiographical) and continuous expanses. The problem, therefore is logistical in nature in that great expanses must be encompassed to study the variety of conditions underwhich agriculture is performed.

The goals of agricultural research can be viewed as being accomplished in a two prong approach:

(1) Observe and evaluate interactions. If none exist, the logistical problem is minimized.

(2) Explain in terms of fundamental principles. These principles are developed at the order just lower than that of interest in hierarchies such as: ecosystems, populations, organisms, systems, organs, tissues, cells, organelles, molecules, atoms.

Since logistical problems are minimized at the lower ends of these hierarchies, more progress has been made at these levels. The machinery, however, is available for studying the higher levels and is the network of experiment stations present in most states (Figure 1). This experimentation is more expensive than we like to admit and is often subsidized in ways we don't like to discuss. This subsidy is often in the form of receipts from produce.

ORGANIZATIONAL FEATURES

One organization of Experiment Stations is the substation approach in which the scientists are located at the main station and support staff are located at substations in different chains of command. In order for research to result from this organization, cooperation (association for common benefit) must occur. This arrangement is sometimes ineffective because the goals of the two parties are different, although never stated to be different. That is, the goal of the scientist is to perform fundamental research, publish, attain tenure and advance in grade, whereas, the goals of the support personnel often include performance of production research, sale of produce, payment of bills and continuance of existence. Some considerations in performing cooperative research are: (1) remember the chain of command, (2) involve the superintendent and support staff at all levels of research (project development and execution), and (3) communicate frequently (confront emerging issues).

Another organization selected by some states is called the center approach and involves scientists located both at the main station and at outlying stations. These scientists are similar in some respects but have different perspectives. At the main station, scientists are closer to the industry and are preoccupied with the clientele. In order for the goals of research to be accomplished, these scientists must collaborate (joint intellectual effort). The needs required by each type of scientist from the collaborative effort are different. Scientists at the main station need a site for research, onsite support and to gain a feel for area agriculture and problems whereas, scientists at outlying stations need rapport, discipline contact and graduate student interaction from the collaborative effort. Some considerations to keep in mind in collaboration are:

1. In project development,
   a. Develop your objectives so that successful execution is not dependent upon activities of your colleague
   b. Define the specific objectives you desire from the collaboration
   c. Determine areas of overlap
   d. Delineate responsibilities
   e. Determine titles, dates and authors of manuscripts
   f. Begin small to develop trust

2. In project execution,
   a. Maintain enthusiasm
   b. Communicate often
   c. Remember your collaborators
   d. Publish (follow through)

CONCLUSION

Because of logistical and communication problems, cooperative/collaborative research is difficult but necessary to solve the goals of research at the resolution necessary to the industry. To pursue these goals (to develop unifying theorems and broadly applicable technology), research at each site must fit into a statewide, regional or national matrix and, therefore, both cooperation and collaboration are required.

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GRAZING EXPERIMENTS - OBJECTIVES, COMPROMISES AND APPROPRIATE DESIGNS

OBJECTIVES OF GRAZING RESEARCH AND THEIR IMPLICATIONS FOR EXPERIMENTAL DESIGN

A. G. Matches [1/]

A complete treatise on this topic is not possible within the time frame available. In fact, a group has met the past two days discussing this topic in some detail in preparation for a symposium at a later date.

I will briefly touch upon thoughts that I have on these topics, information gleaned from the literature, and conclude with a quotation from Gill which I believe is very appropriate for the discussion of Dr. Bransby which follows.

WHY GRAZING EXPERIMENTS?

More than one research administrator and experiment station director has, over the years, questioned whether grazing experiments are really necessary. From us they have become aware of several "truisms":

1. High costs per treatment as compared to other field experiments.

   a. Sizeable land requirements
   b. Large investment in livestock
   c. Fencing and watering facilities
   d. Maintenance cost
      - physical facilities
      - animal health
      - fertilizer
      - weed control in experimental area
      - irrigation (where used)
   e. Duration of experiments usually 3 to 6 years

2. Quite labor intensive if conducted properly.

   a. Animal management
   b. Animal health
   c. Monitoring to characterize the sward over time

3. Involve complex relationships which are not easily delineated.

   a. Plant/animal
   b. Soil/plant/animal
   c. Management/....etc.

4. High experimental variability not uncommon.

   a. Two biological systems imposed on each other
   b. Less statistical sensitivity than in many other kinds of research

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One might conclude from the above that many of us have selected careers which are constantly in jeopardy in one way or another.

PURPOSE OF GRAZING EXPERIMENTS:

Short-term and long-term goals may be achieved from conducting good grazing trials. In the short term (mainly a number of separate experiments), grazing research can:

1. Depict the animal influence on sward and soil.

   a. Herbage dry matter production
   b. Influences on plant morphology
   c. Regrowth potential under grazing
   d. Changes in botanical composition
   e. Persistence
   f. Soil compaction
   g. Soil conservation
   h. Nutrient transfer
   i. etc.

2. Depict the sward influence on animals.

   a. Output per animal as influenced by:
      - herbage availability (fertilization, species, stocking rates, etc.)
      - canopy structure
      - forage quality
      - plant morphology
      - anti-quality factors
      - etc.
   b. Animal health
      - anti-quality factors
      - morphological factors

3. Identify pasture/management components for pasture/livestock systems.

In the long term, grazing trials provide the basis for designing and testing pasture systems for:

1. Specific classes of livestock.
2. Specific environmental constraints.
3. Specific types of markets.
4. Different economic scenarios.

Certainly expenditures on grazing research are justified. However, Morley (1978) has emphasized the need for a systems approach in grassland evaluation. He suggests that the greatest progress will arise from the combination of mathematical modeling (systems analysis) and field experimentation. Based on my review of over 70 U.S. grazing research papers that have been published in the past 20 years, it is apparent that we should give more attention to describing functions related to the plant/animal interface. Such information in the hand of modelers will ultimately pave the way for us to plan even more comprehensive grazing trials in the future.

DESIGNING THE EXPERIMENT:

Designing research should include the following three important steps (Cook and Stubbendieck, 1986):

1. Clearly define and prioritize the objectives of the research and give the hypothesis. The null hypothesis (no differences among treatments) is most commonly used, but in some cases the alternative hypothesis may be more appropriate.

2. Describe the experimental material, treatments to be investigated, and conditions under which treatments will be compared. These all influence the selection of the most appropriate experimental design.

3. Describe the measurements to be recorded, the precision desired, and the type of conclusions to be drawn (how are results to be applied).

Too often, pasture plantings are made before the researcher has given adequate thought to the above points. Consequently, the experimental design selected when planting may not be entirely appropriate to meet the objectives and intended application of results. In planning experiments, I find that keying out the analysis of variance for different designs and combinations of treatments is very helpful for selecting the final design and make-up of the experiment. In some cases following this exercise, I have decided that with the resources available, the intended research could not be effectively conducted.

EXPERIMENTAL DESIGN: COMMENTS AND CONSIDERATIONS:

My comments are limited to grazing experiments where both animal production and plant responses to grazing (objectives 1 and 2 above) are investigated concurrently within the same experimental pastures.

Two types of trials that are in common use are continuous trials and change-over trials (Lucas, 1959). In continuous trials, animals remain on the same treatment for the duration of the experiment. In change-over trials, animals are subjected to at least two or more experimental treatments during the course of investigation. Most grazing trials are of the continuous type and utilize a randomized complete block (RCB) or a split-plot (SP) design. Because so few treatments are usually investigated in grazing trials and because of certain statistical limitations, other experimental designs such as the latin square and lattice are used less frequently.

The impact of experimental design on the application of grazing results is covered by Brown and Waller (1986), especially in respect to replicated vs. unreplicated experiments. Walker and Richardson (1986) also discuss the matter of replications in grazing studies. Replications are necessary in order to perform tests of significance of treatment effects related to land area in the analysis of variance. Brown and Waller state that "experimental design of comparative range and pasture grazing trials should include sufficient replication of land, animals, and time to properly estimate variance at an acceptable level of precision for characterization or inference." In their opinion, unreplicated pasture studies can serve as a screening trial for several treatments which may be included in replicated trials which follow. In the following paper, regression techniques which do not require field replications are discussed by Dr. Bransby.

As stated by Walker and Richardson (1986) from a reference source, "an experimental unit or experimental plot is the unit of material to which one application of a treatment is applied." In grazing experiments where animal performance is measured, the experimental unit is the pasture (Brown and Waller, 1986; Cook and Stubbendieck, 1986; Morley, 1978). Therefore, the animal-to-animal source of variation may not be considered by some as an appropriate error component for testing resulting treatment differences in animal performance.

Where rotational grazing is followed in grazing experiments, some researchers move animals among replications to achieve rotational grazing. But as explained by Mott (1959), weight increase for an animal over each weigh period (W_n) is represented by the following equation for four weighings:

$$\text{Weight increase} = [W_2(e) - W_1(e)] + [W_3(e) - W_2(e)] + [W_4(e) - W_3(e)]$$

where "e" is the error associated with each weighing. Therefore, in rotating animals among replications, the errors of each weighing are accumulated and this inflates the error term in the analysis of variance. Mott recommended that each pasture be subdivided into paddocks and animals rotated within each pasture. Then, over the four weigh periods, all but the weighing errors on the first and last weighing would cancel out as follows:

$$\text{Weight increase} = [W_4(e) - W_1(e)]$$

Matches (1969) showed a hypothetical situation where rotating animals among replications might result in a true interaction of "replication x treatments". This would further inflate the experimental error in a simple RCB design experiment since the RxT interaction is normally the error term for testing treatment differences

Change-over trials are of two types, rotational and switch-back or reversal. When used properly, change-over trials may reduce experimental errors associated with the variability among animals (Lucas 1960). Normally, change-over trials are used only where treatment effects do not have a strong carry-over effect on the animal (Gill, 1981; Lucas, 1963). Because pasture treatments usually have large carry-over effects on animals, change-over trials are not generally recommended for use in grazing trials.

COMPONENTS VS. PASTURE SYSTEMS:

Pasture systems consisting of separate pastures of different forages or management schemes are useful for extending grazing and providing higher quality herbage throughout the grazing season (Matches, et al., 1974; Matches, 1981). Components of such systems are generally first evaluated "individually" in conventional grazing trials. Sometimes, researchers are tempted to use component data from several experiments to project what animal performance would be if different components were grouped to form pasture systems. Projected animal performance (daily gain/head and gain/ha) likely will be inaccurate. For example, Matches, et al. (1974) and Matches (1981) found that eight forage components had a spread of 459 g for daily gain and 295 kg for gain/ha. In comparison, under grazing the spread among ten pasture systems comprised of the various components was only 204 g for daily gain and 78 kg for gain/ha. Similar results were reported from other experiments. Apparently, compensatory gain responses (positive and negative) of cattle resulted in a leveling-out of gains in the systems. Therefore, projections of cattle performance should not be made based on the combined results from single component grazings.

Related to the above is the question of whether animals should be rerandomized when moving from one component to another in a pasture systems trial. This has been done in some pasture system experiments. Because the experimental unit is a pasture system comprised of two or more components, and because the system is the variable of concern when applying the results, I would not rerandomize animals when animals are shifted among components. Compensatory gain effects of animals would be masked so that the system potential could not be accurately measured.

DEALING WITH DIFFERENCES IN GROWTH PATTERN AMONG FORAGES:

With cultivar evaluations and pasture component research, it is not unusual to have pastures of different forages which are not all ready for grazing at the same time because of inherent differences in time and rapidity of initial growth. Should grazing be delayed until "all" entries have sufficient growth for grazing? Or should grazing begin on "each" entry when its growth is ready? In my opinion, researchers and producers should "read the plants and not the calendar." Delaying grazing of early growing entries means lost quality and lost animal gain. Certainly, wise producers will graze each of their forages when it is ready; consequently, if research is to meet the producers' needs, grazing should be initiated for each entry when it reaches its proper stage of growth.

FUTURE NEEDS:

Funding limitations, land availability, and other factors often restrict the scope of many grazing trials. Replicating pastures is expensive and minimizes the number of treatments that can be investigated. We need the help of statisticians who can devise experimental designs which will give us reasonable precision and still allow the testing of more treatments per trial. Gill (1981) has suggested for feeding experiments that wider use of regression techniques, multivariate procedures, and response surface designs might offer opportunities as more flexible computer programs become available in the future. But he also cautions that "perhaps the greatest source of inertia holding back the wheels of progress in statistical applications is the occasional professor who insists that his research students ignore their modern instruction in statistical methodology and do it his way." Hopefully, new statistical procedures and open minds will give us the tools to meet the research challenges of the future.

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ADVANTAGES OF A NON-REPLICATED MULTIPLE GRAZING INTENSITY APPROACH FOR GRAZING TRIALS

David I. Bransby[1]

Introduction

The procedures and design used in any grazing trial will depend largely on the objectives of that trial. However, financial and logistical constraints such as limited labor, land, paddocks, animals etc. are almost always severely restricting. No matter what the objectives of a grazing trial are, therefore, compromise is usually necessary. This compromise requires determination of an acceptable balance between biological or practical value and applicability of results on the one hand, and on the other, scientific value. In other words, grazing research data should ideally be applicable to the producer and/or reveal new biological information, and be scientifically testable or assigned a level of probability.

It might be argued that component research (as opposed to systems research) need not necessarily be practically applicable. This is true, but if experimental designs and procedures that have practical, biological and scientific merit can be developed, this will make more efficient use of limited available resources for grazing research. Futhermore, in animal production systems such as beef enterprises, a component of a system can represent a simple system in itself. For example, many producers in the south buy calves, grow them out on pastures, and sell them, and this simple system is simulated by a large proportion of beef grazing trials. It is therefore desirable that data from such trials be well suited to economic analysis (2). The objective of this paper is to discuss the biological, practical and scientific merit of traditional procedures, and an alternative multiple grazing intensity procedure for grazing trials.

Traditional procedures

The traditional approach to grazing research in the U.S. has included (a) the put-and-take method of stocking, (b) usually only one grazing intensity (one grazing pressure, forage availability or level of forage on offer) for a whole experiment (occasionally grazing intensity has been confounded with treatment), and (c) a randomized complete blocks design with two or three replications. The objectives of the put-and-take method of stocking have been (1) to maintain grazing intensity constant across replications and treatments over time, (2) to ensure that animal potential is above pasture potential at all times, and (3) to facilitate use of average daily gain (ADG) as an animal measure of forage quality, and animal grazing days per unit area (or average stocking rate) as a measure of forage quantity (15). In other words, the last objective represents an attempt to avoid confounding of forage quantity and quality as it affects animal performance. This concept clearly has considerable biological and scientific merit.

Strengths and weaknesses of the traditional approach

The main strengths of the traditional approach are the "pure" error term provided by replication, and the flexibility afforded by put-and-take stocking to adjust for the unknown, such as unpredictable weather, no previous information on new treatments, and new environments. On the other hand, several weaknesses are apparent. (a) The optimum grazing intensity is seldom (if ever) defined, and cannot be identified without mutliple grazing intensity (or stocking rate) research. (b) Treatment x grazing intensity interactions cannot be detected if only one grazing intensity is used. Since these interactions are probably common in grazing systems, results from single grazing intensity studies may apply only to the grazing intensity used. (c) Grazing intensity (as determined by kg available forage per unit area) cannot be perfectly measured, or perfectly replicated by means of the put-and-take method of stocking. In some cases, control of forage availability may be poor (16). This means that forage availability is confounded with replications, treatments, years etc., in which case ADG cannot be used as a measure of forage quality, and animal grazing days per unit area is not a reliable measure of forage quantity. (d) Put-and-take of animals is not common farm practice (put-and-take of land and/or time might be more applicable here) and is not well suited to economic analysis (12). (e) The basis for put-and-take of animals appears to have been highly variable among workers (eg. kg forage/animal, kg forage/animal/day, kg forage/ha, forage height, residual

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forage etc); therefore, results may not be comparable across workers.

The traditional approach could be improved in several ways. Firstly, if only one grazing intensity is used in an experiment, forage availability should be measured and analysed to show the degree to which it was controlled by put-and-take. It should also be expressed in a form which reflects ease of prehension by the grazing animal, such as height or density (6,7). Weight of forage per animal unit may not adequately reflect this. For example if a 2-ha and a 10-ha pasture each contained 2000 kg of forage and 10 animals, kg of forage/animal is the same, but intake and animal performance are likely to be very different. Secondly, if forage availability was not successfully equalized across treatments and replications by put-and-take in a single grazing intensity trial, it may help to use forage availability as a co-variate in an analysis of covariance. Finally, from a practical and economic viewpoint, it would probably be better to put-and-take land and/or time instead of individual animals, and to make these adjustments relatively infrequently.

The need for multiple grazing intensity trials

It is of great value in a grazing trial to apply several treatments at several (preferably at least four) grazing intensities, which may constitute different levels of forage availability achieved with put-and-take, or different fixed stocking rates (1,2,5,8,10,13,17). Multiple grazing intensity trials are needed because; (1) treatment x grazing intensity (stocking rate) interactions can be detected; (2) optimum grazing intensity varies among treatments; (3) economic optimum grazing intensity varies with buying and selling price of animals (3,4,11,14,18); (4) it is not necessary to perfectly repeat a level of forage availability to use ADG as an index of forage quality, since regression lines are used in the analysis, and not single points; and (5) it is very important to establish the heaviest grazing intensity a pasture can tolerate without losing stand, since stand longevity is probably the trait most valued by producers in a perennial species, and under production conditions there are inevitably going to be times when heavy grazing is unavoidable. Financial and logistical constraints will clearly make it difficult to apply several treatments at 3 or 4 stocking rates (preferably 4) and 2 or 3 replications. However, a regression approach (which is a well recognized statistical procedure) facilitates statistical analysis without replication (9,17,19).

Analysis and interpretation of data from non-replicated, multiple grazing intensity trials

To analyse and interpret data from non-replicated, multiple grazing intensity trials it is necessary to examine three regression relationships; ADG vs. stocking rate, ADG vs. forage availability and forage availability vs. stocking rate (5). These regressions can be developed from several treatments and compared by testing for differences among slopes and intercepts of the lines. In the broadest sense, testing for statistical differences among treatments in a scientific experiment involves comparing variation which can be accounted for (by treatments, blocks, regression coefficients, etc.) with variation that cannot be explained (the error term): if the former is large relative to the latter, then statistical significance is indicated. In the case of a non-replicated, multiple grazing intensity design, deviation from regression is the only variation that cannot be explained, since all other variation is accounted for by treatments and regression coefficients. Viewed in another way, each treatment can be considered as replicated, but replicates are confounded with grazing intensity or stocking rate. The data could then be analysed by analysis of covariance, with grazing intensity or stocking rate as the covariate. Differences between stocking rates cannot be tested, but this is of little consequence provided other experimental variables are not confounded with stocking rate.

Differences among treatments in the ADG vs. stocking rate regression (1,8,13,17) are of little value if they are not linked to forage availability because separate effects of forage quality and quantity on production per animal cannot be determined (Fig. 1). However, this relationship forms the basis for economic analysis (3,4,11,14,18). Differences among treatments in the ADG vs. forage availability regressions represent differences in forage quality (Fig. 2), while differences in the forage availability vs. stocking rate regression represent differences in yield or "carrying capacity" at a particular forage availability (Fig. 3). These three relationships provide a basis for

relating gain/ha and profit to stocking rate and forage availability. Optimization procedures can then be used to determine the level of forage availability or stocking rate that maximizes gain/ha or profit (3,4,11,14,18).

Furthermore, inherent differences among paddocks are likely to be expressed mainly in terms of forage availability. Consequently, the ADG vs. forage availability regression (Fig. 2) will largely remove this variation which will appear as deviations from regression in the ADG vs. stocking rate and available forage vs. stocking rate regressions (Fig. 1 and Fig. 3). Consequently, measurements of forage availability are critical in analysis and interpretation of data from non-replicated, multiple stocking rate grazing trials.

Conclusion

The non-replicated, multiple grazing intensity approach represents an extremely attractive compromise between scientific, practical and biological needs in grazing trials.

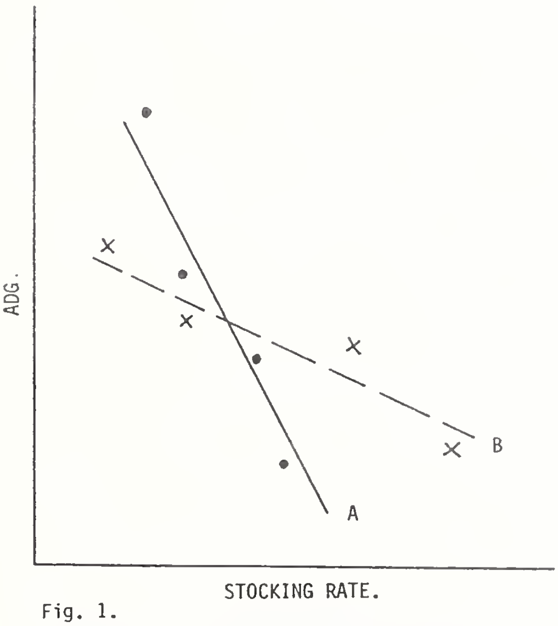

Fig. 1.
Relationships between ADG and stocking rate for hypothetical treatments A and B, showing a typical treatment x stocking rate interaction (different slopes).

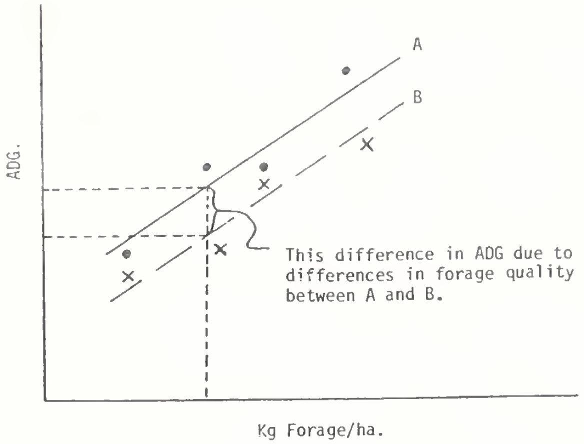

Fig. 2.
Relationships between ADG and kg forage/ha for hypothetical treatments A and B, showing a typical main effect (parallel lines) which can be ascribed to differences in forage quality between A and B.

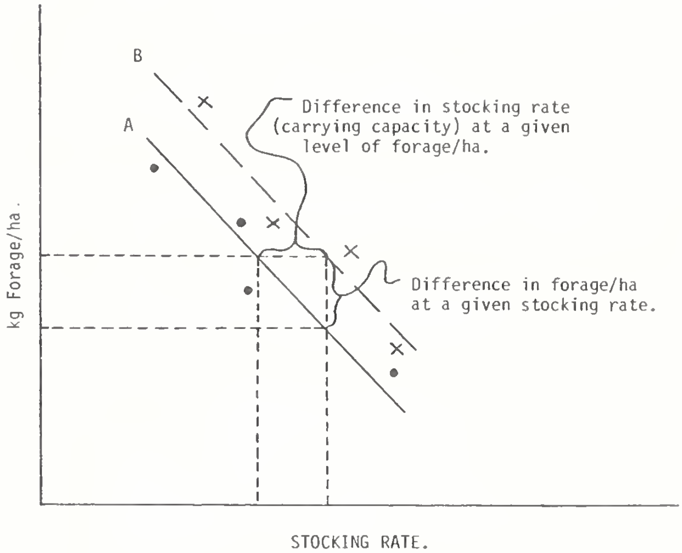

Fig. 3.
Relationships between kg forage/ha and stocking rate for hypothetical treatments A and B showing a typical main effect (parallel lines). This relationship indicates quantitative effects: the difference in stocking rate at a given level of forage/ha, or the difference in forage/ha at a given stocking rate.

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STATISTICAL ASPECTS OF GRAZING EXPERIMENT

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SUMMARY

Research designs available for the study of forage crop improvement and grazing trials are many and varied. The ability to detect treatment differences depends almost entirely on the foraging meat-producing model and the research design actually used. Small changes in the designs can increase or decrease sinsitivity of statistical tests substantially by virtue of the mean squares used as error variances. In this report examples of hypothetical and actual experiments are evaluated and compared from the viewpoint of statistical designs of research plans.

INTRODUCTION

In row crop and grain experiments, land is divided into plots. Treatment variables are applied to the plots, and at the appropriate times, yields are measured. If yield is measured as a single number for a plot, then random variability among plots cannot be measured directly without replicating the experiment. Let us consider a randomized block experiment wherein strips of land called blocks are subdivided into plots of nearly equal sizes. In fact, they are always treated, statistically, to be exactly the same size. Following the subdivision of the strips, treatment variables are randomly assigned to the plots within the blocks.

The statistical "effects" of the experiment are assignable to Treatments and Blocks and their interactions, and in most cases, both are considered "fixed". The linear additive model and the analysis of variance (ANOVA) (Table 1) have the following forms:

$$Y_{ij} = M + B_i + T_j + BT_{ij} + E_{ij} \qquad (1)$$

wherein M is the overall population mean; B_i are the block effects, and T_j are the treatment effects. If the treatment effects are not constant from block to block, then the term BT_{ij} is added. Random variation, E_{ij}, is omnipresent whether it can be measured or not.

Blocks are usually ignored. To test the hypothesis that there is no treatment effect or that the treatment effect is constant across all treatments, the variance ratio

$$F = MST/MSE \qquad (2)$$

should be used and compared to the upper percentage points of an F with df (degrees of freedom) equal J-1 and (I-1)(J-1). But this F cannot be calculated because there is only one observation per plot, and the random variation between plots cannot be estimated. What is usually done (Steel and Torrie, 1980, p. 195 or Montgomery, 1984, p. 211) is to replace (2) with

$$F = MST/MSBT \qquad (3)$$

by assuming, correctly or not, that the B by T interaction is zero. Thus, (3) is a central F statistic if and only if T_j and BT_{ij} are both zero for all combinations of i and j. The hypothesis of no treatment effect is rejected, if the calculated variance ratio equals or exceeds the tabulated value for a given error rate, say, 0.05 or smaller.

If for any reason it is known or believed that the forgoing interactions BT_{ij} are not zero, then the experiment must be designed to include estimates of the error variance, V_e. Equation 1 would be rewritten to reflect the same, namely

$$Y_{ijk} = M + B_i + T_j + BT_{ij} + E_{k(ij)}, \qquad (4)$$

and Table 1 would change to Table 2.

Now, the denominator in (3) is replaced with the MSE:

$$F(Trtmnt) = MST/MSE, \text{ and}$$
$$F(BxT) = MSBT/MSE. \qquad (5)$$

One answer to the presence of interactions in row crop experiments is replication within every treatment, thereby allowing for an estimate of the error variance. Even though there may be variability from plot to plot, in general, there is no great concern expressed over it. This is not true in grazing experiments.

When blocking is not available, desirable or less than artificial, the experiment may resolve to that of one completely randomized over experimental units. Let us consider one illustrated completely in Steele and Torrie (1980, p. 153).

Treatments are applied to the soil within pots within a greenhouse. Mint roots (plants) are planted in equal or varying numbers in each pot. The resultant linear additive model for equal numbers of roots within all pots is

$$Y = M + T_i + P_{j(i)} + R_{k(ij)} \qquad (6)$$

wherein, M is the grand mean; T_i is treatment effect, $P_{j(i)}$ is the between Pot variability and $R_{k(ij)}$, the between root variability. T_i is externally imposed and considered to be an effect fixed in nature. Both $P_{j(i)}$ and $R_{k(ij)}$, are random variables and measure variation from pot to pot and

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from mint root to root. The skeletal ANOVA is found in Table 3.

Since the pot mean square is the error term for testing one treatment against another, the ability to detect differences among treatments rests in the number of pots which can be properly maintained within the greenhouse. However, the number of plants within a pot could be a factor of the treatment. Then, in spite of our wishes, the number of roots per pot is dictated by the treatment itself and can be used as a concomitant variable to measure root pressure or root intensity. If, in addition to root pressure, the experiment were carried out in the open, not in a greenhouse, then a second concomitant vari-able could also be used, namely rainfall. These would alter (6) as follows:

$$Y_{ijk} = A + B_1N_{ij} + B_2W_{ij} + T_i + P_{j(i)} + E_{ijk}, \qquad (7)$$

wherein, A replaces M and is considered the intercept; B_1 is the regression coefficient for the number of roots per pot, and B_2 is that for inches of water (rain) received by the pots. $R_{k(ij)}$ is now replaced by E_{ijk}, the residual error after extracting $SS(B_1, B_2)$. SSE is used to test A, B_1, and B_2, while SSP remains the error term to test T unless the following is true.

Suppose the soil within each pot comes from the same batch as for every other pot and the only differences, practically speaking, come from N_{ij} and W_{ij} which are then surrogates for $P_{j(i)}$. Equation 7 makes one more metamorphic leap to become

$$Y_{ijk} = A + B_iN_{ij} + B_2W_{ij} + T_i + E_{ijk}. \qquad (8)$$

At this juncture MSE is the error term for all comparisons. SSP has been absorbed by SSE which is now $SSR\text{-}SS(B_1,B_2)+SSP$.

DESIGNS FOR GRAZING EXPERIMENTS

Comparisons with Standard Designs

Each of the foregoing models will be recast into designs which could be used in grazing trials. Strengths and weaknesses of each will be discussed from the viewpoint of efficiency of use of experimental materials. Lastly, the statistical power of the test will also be discussed.

Design 1: Paddocks are IJ in number. They are assigned to I groups as nearly homogeneous as possible and are called Blocks. The paddocks do not have to be contiguously arranged. To each of the I blocks J treatments are randomly assigned. A treatment, let us remember, is a combination of externally imposed conditions or applications. A treatment could consist of a particular combi-nation of components taken from a) fertilizer kind and rate applied to the soil, b) species or variety of grass, clover or mixture of foraging crops, c) supplemental feeding, d) sources of water for the soil, e) stocking rate, f) other possible factors. Stocking rate will be treated separately from all others because the grazing animal is the material which gives us our measurement, and it can also be part of the treatment itself.

a) Among the J treatments, stocking rate is held constant. Then (1) is the linear additive model. The response variable is total weight gained per unit area and animal to animal variation contributes nothing to the experiment. Treatments are tested using MSBT, and the power of the test depends entirely on df = (I-1)(J-1).

b) Stocking rate is a factor of the treatment combination but it is not considered to be an interval measure. Then, there is no change in the above model.

c) Stocking rate is considered an interval measure and separate from all other variable combinations which make up a treatment. Then, (1) is altered and becomes

$$Y_{ij} = A + Cf(S_{ij}) + B_i + T_j + E_{ij} \qquad (9)$$

wherein A is the intercept; C is the regression coefficient for $f(S_{ij})$, the response function for the intensity of stocking or grazing pressure; and E_{ij} is the residual error. The response variable is again total gain per unit area.

Design 2: Paddocks are IJK in number. The design is that of Design 1 above with K replicates of each block by treatment combination. The linear additive model is that of (4), and the response variable remains total gain per paddock or normalized to accepted units of area (hectares or acres). Equation 5 would be used for testing, if stocking rate were considered a nominal measure, but linear additive model (9) would be used if a response function were used to measure effects of varying stocking rates.

Design 3: Treatments are I in number, and each is applied to J paddocks containing N_{ij} animals. The linear additive models are those of (6), (7) and (8) or more generally,

$$Y_{ijk} = A + B_1f(S_{ij}) + B_2g(W_{ij}) + T_i + P_{j(i)} + E_{ijk} \qquad (10)$$

or

$$Y_{ijk} = A + B_if(S_{ij}) + Cg(W_{ij}) + T_i + E_{ijk} \qquad (11)$$

depending on whether S_{ij} and W_{ij} are adequate surrogates for paddocks $P_{j(i)}$.

Design 4: A Complex example: This hypothetical experiment is typical of grazing research experiments. It consists of JK treatments composed of K stocking rates together with J combinations of other treatment factors. The entire experiment is repeated for I years. Instead of water available to the soil, forage available to the grazing animal is measured. Weight gain is measured on each animal from which other measures of production can be calculated. Forage availability is taken as a surrogate for paddock effect and its response to the T_j by S_k combination. Thus, we are mapping the complex interaction of paddock by treatment by stocking rate into forage availability, which in turn is a concomitant regression variable with a causal effect on weight gain for the animal.

The linear additive model is

$$G_{ijkl} = B_0 + B_1F_{ijk} + Y_i + T_j + TY_{ij} + S_k + YS_{ik} + TS_{jk} + YTS_{ijk} + A_{l(ijk)}, \qquad (12)$$

wherein G_{ijkl} = weight gain,

B_0 = Intercept,

B_1 = Regression coefficient, assuming, linear dependence between forage availability and weight gain,

F_{ijk} = Forage availability,

Y_i = Year to year effect,

T_j = Treatment (other than S_k) effect,

S_k = Stocking rate effect,

$A_{l(ijk)}$ = Animal effect, and YT,YS,TS and YTS are the respective interactions.

Both T_j and S_k are considered fixed effects since they are predetermined by the persons conducting the experiment, while both Y_i and $A_{l(ijk)}$ are random variables.

Table 4 is the skeletal ANOVA table for (12) includes the degrees of freedom and the mean square error used to test each term.

SSF is a partition of SSYTS since F_{ijk} is completely confounded with YTS_{ijk}, except that F_{ijk} is a continuous regression variable whereas YTS_{ijk} is discrete. Thus, the degree of freedom for F_{ijk} is subtracted from df for YTS_{ijk} and not $A_{l(ijk)}$.

Because the error mean squares for T_j and S_j are the YT and YS mean squares, respectively, this design has a major flaw. The role of the animal mean square is that of testing components of variance of Y and its interactions and the very important regression coefficient, B_1, of F_{ijk}. In order to gain respectable degrees of freedom of error to be used when testing T_j and S_k it becomes necessary to rerun the exact same experiment which usually requires a period of several years.

An interesting collapse of Table 4 occurrs for I=1. That is, if the experiment is run for only one year, then Table 4 becomes Table 5.

When I=1, the only random effect is due to animal, $A_{l(ijk)}$, and the power of the various tests depends on JK($\underline{L}$-1) the total number of animals, JK$\underline{L}$, minus the number of paddocks, JK. JK($\underline{L}$-1) can be a number of reasonable size and which allows differences to be detected that are due to both stocking rates and the other variables of the treatments.

What is wrong with the design in which the same experiment is repeated over a number of years, and how can it be corrected? The strong dependence on the number of years is evident in (12) and Table 4 because the EMS df is always that of a Year by Treatment Interaction. This is the flaw. It can be corrected rather simply. Each year, retill all paddocks; reassign all JK combinations of T_j and S_k to the JK paddocks. Then each replicated experiment will be embedded or nested within each year. This clearly has relevance only to annual pastures. Within Table 5 add a line for Y_i with df I-1 and MSE = MSA. Multiply all other df by I because the linear additive model is

$$Y_{ijkl} = B_0 + B_iF_{ijkl} + Y_i + T_{j(i)} + S_{k(i)} + TS_{jk(i)} + A_{l(ijk)}. \qquad (13)$$

With this replicated experiment one cannot only obtain measures separating the T_i, S_k and TS_{jk}, but s/he can also test for year-to-year variability of the effects of forage availability, F_{ijkl}, by testing for parallelism from year to year.

CRITIQUE OF SOME PUBLISHED DESIGNS

Riewe (1961) reviewed a number of past trials, giving their results and setting forth a design in which replication was not used or needed. His Table 1 gives 14 correlations between stocking rate and gain per animal. Most of the correlations have only one df for error. An r = -.999 has a significance of only .028473 with

df=1. However, the sum of -2log(p) over the 14 tests of significance on the correlations is a chisquare with df = 28 (See Sokal and Rohlf, 1981, p.779). In this case it results in a chisquare equal to 96.95 and a level of significance of 1.7 in a billion. The evidence is very strong that average gain per animal can be expressed as a linear function of stocking rate.

When Riewe considered replication, whether on purpose or not, he treated a replication as a block and uses the block by treatment interaction as error. His table 3 with F, P and X^2 added and its replacements are here presented as Table 6a and 6b.

The linear additive model used is that of (1) when it should have been that of (6) without the $R_{k(ij)}$ term. Here, he has lost two degrees of freedom for error, and the overall level of significance (p-value) was four and one-half times as large as it should have been.

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His claim that a linear relationship is adequate to express gain per animal as a function of stocking rate is well supported and leads to the following:

$$G = A + BS \quad \text{(Kg or lb.)/animal,} \qquad (14a)$$

$$= AS + BS^2 \quad \text{(Kg or lb)/(ha or ac,)} \qquad (14b)$$

$$\text{and} \quad S_{max} = -.5A/B, \qquad (14c)$$

wherein A and B are regression coefficients; S is stocking rate (animals per area), and B is negative.

Petersen, Lucas and Mott (1965) developed a theory linking stocking rate and per animal and per area performances but did not address designs. Their initial assumption "Amount and type of forage available per acre are independent of stocking rate" has been shown to be unrealistic by (Conrad, Holt and Ellis, 1981. In fact, as stocking rate increases, forage availability decreases.

Conniffe (1976) sets out to compare between and within herd variances by collecting data from 12 experiments where both of these could be estimated. His model for error is

$$E_{ij} = A_{ij} + C_{ij} + H_i \qquad (15)$$

with expected mean squares of

$$\text{EMS(between)} = V_a + r\,V_h \qquad (16a)$$

$$\text{EMS(within)} = V_a + V_c \qquad (16b)$$

wherein A_{ij} = animal effect

C_{ij} = competition, and

H_i = herd effect.

He argues away C_{ij} by summing it to zero over the herd. This is incorrect! C_{ij} is inexorably confounded with and is a part of the animal variability itself and should not be part of the model at all. Removing V_c in (16b) gives the correct EMS. What is more, the linear additive model for the data he reports is that of (6) in which $H_{j(i)}$ replaces $P_{j(i)}$ and $A_{k(ij)}$ replaces $R_{k(ij)}$. In every case which he reports in his Table 3, the F test should be a one-tailed, right-tailed test. He incorrectly uses a two-tailed test in every case. His Table 3 is here reproduced as Table 7 with the correct value of the F statistic and a column added for the probability of a larger F, where
F = Between Herd MS/within Herd MS.

Again, the sum of -2log(Pr>F) is a chi-square with df equal to twice the number of independent tests of significance. In this case X^2 = 33.745; df = 24 and Pr > X^2 = 0.0893. This alone is enough to fail to reject the hypothesis that the between-herd component of variance is zero. But Coniffee impeaches his 1964-Moorepark data, the one very large between-herd estimate of the variance. If we exclude that test, then X^2 = 18.944, df = 22, and Pr > X^2 = 0.649. This would lead me to conclude that the between-herd variance is either negligible or simply nonexistent.

CONCLUSION

Other studies could be included, but that would be stretching the point. From my perspective, empirical forage research has advanced to the point that it is inseparable from that of mathematical and statistical modeling. There is an unlimited number of designs available for use in conductinng grazing research. Whether replication of one kind or another can/must be used depends entirely upon the modeling s/he is willing to use and defend. Experimental materials are very expensive in this research, which goes almost without saying. A small quirk in the experiment as actually performed, against all good intentions, can result in loss of degrees of freedom in the error mean square and diminish the power of the test to the point of voiding the entire experiment. Caveat emptor!

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Table 1: Skeletal ANOVA for a two-way completely crossed experiment (Randomized Complete Block). S_i, S_iS_j, etc. indicates a sum over all values of i, i and j, etc., respectively. V_e is the error variance.

Source	df	SS Contrast	Expected Mean Square
Blocks	I -1	$\underline{Y}_{i.} - \underline{Y}_{..}$	$JS_iB_i^2/(I-1) + V_e$
Trtmnt	J -1	$\underline{Y}_{.j} - \underline{Y}_{..}$	$IS_jT_j^2/(J-1) + V_e$
BxT	(I-1)(J-1)	$Y_{ij} - \underline{Y}_{i.} - \underline{Y}_{.j} + \underline{Y}_{..}$	$S_iS_jBT_{ij}^2/((I-1)(j-1)) + V_e$
Plots	IJ -1	$Y_{ij} - \underline{Y}_{..}$	-------
Error	0	Not Available	Not Available
Total	IJ -1	$Y_{ij} - \underline{Y}_{..}$	-------

Table 2: Skeletal ANOVA of a two-way completely crossed experiment with replications within every ij combination.

Source	df	SS Contrasts	Expected Mean Square
Blocks	I -1	$\underline{Y}_{i.} - \underline{Y}_{..}$	$JKS_iB_i^2/(I-1)+V_e$
Trtmnt	J -1	$\underline{Y}_{.j} - \underline{Y}_{..}$	$IKS_jT_j^2/(J-1)+V_e$
BxT	(I-1)(J-1)	$\underline{Y}_{ij.} - \underline{Y}_{i..}$	$KS_iS_jBT_{ij}^2/((I-1)(J-1))+V_e$
Plots	IJ -1	$\underline{Y}_{ij.} - \underline{Y}_{...}$	-------
Error	IJ(K -1)	$Y_{ijk} - \underline{Y}_{ij.}$	V_e
Total	IJK -1	$Y_{ijk} - \underline{Y}_{...}$	-------

Table 3: Skeletal ANOVA of a completely nested experiment.

Source	df	SS Contrast	Expected Mean Square
Trtmnt	I-1	$\underline{Y}_{i..}-\underline{Y}_{...}$	$JKS_iT_i^2/(I-1)+KV_p + V_r$
Pot	I-1	$\underline{Y}_{ij.} \quad -Y_{i..}$	$KV_p + V_r$
Root	IJ(K-1)	$Y_{ijk} -\underline{Y}_{ij.}$	V_r
Total	IJK-1	$Y_{ijk} -\underline{Y}_{...}$	-----

Table 4: Skeletal ANOVA giving degrees of freedom and identifying appropriate error mean squares for testing various components of the linear additive model. $\underline{L}$ is the average number of animals per paddock.

Source	df	Error Mean Square
F_{ijk}	1	A
Y_i	I-1	A
T_j	J-1	YT
YT_{ij}	(I-1)(J-1)	A
S_k	K-1	YS
YS_{ik}	(I-1)(K-1)	A
TS_{jk}	(J-1)(K-1)	YTS
YTS_{ijk}	(I-1)(J-1)(K-1)-1	A
$A_{l(ijk)}$	IJK($\underline{L}$-1)	---
Total	IJK$\underline{L}$-1	---

Table 5: Skeletal ANOVA giving degrees of freedom and identifying appropriate error mean squares for testing various components of the linear additive model.

Source	df	Error Mean Square
F_{jk}	1	A
T_j	J-1	A
S_k	K-1	A
TS_{jk}	(J-1)(K-1) -1	A
$A_{l(jk)}$	JK($\underline{L}$-1)	---
Total	JK$\underline{L}$-1	

Table 6a: Riewe's Table with F/P, chisquare and overall significance added.

Source	df	Mean Square 1957	F/P	Mean Square 1958	F/P
Reps	2	264	–	1969	–
Stocking Rate	1	5891	38.5	7350	8.06
Error	2	153	.025	912	.105

$X^2_4 = 11.89$ $\qquad Pr>X^2_4 = .018$

Table 6b: Replacement of Riewe's Table 3 with F/P, chisquare and overall significance added.

		Mean Square 1957	F/P	Mean Square 1958	F/P
Stocking Rate	1	5891	28.3	7350	5.10
Reps	4	208.5	.006	1440.5	.087

$X^2_4 = 15.12,$ $\qquad Pr>X^2_4 = .004$

Table 7: Conniffee's Table 3 with abbreviated Experiment caption, corrected Fs and Pr > F added.

Experiment	Between Herd	df	Within Herd	df	F	Pr > F
1963, Moorepark	1,770	2	704	76	2.33	.10421
1964	4,200	2	514	76	8.17	.00061108
1965	664	2	421	78	1.58	.21250
1966	58	2	638	78	.091	.91311
1967	271	2	734	79	.369	.69261
1968	1,472	2	663	34	2.22	.12411
1969	82	2	422	80	.194	.82404
1970	1,275	3	687	131	1.86	.13953
1967, Grange	145	3	345	29	.420	.74002
1968	150	3	323	30	.464	.70954
1969	89	3	337	30	.264	.85077
1970	171	4	533	36	.321	.86204

FORAGE BREEDERS INFORMATION EXCHANGE GROUP

BREEDING SELF POLLINATED FORAGE LEGUMES[1]

D. D. Baltensperger[2]

"Self-pollinated forages are mostly annuals. In general, they are grown less extensively and have less economic importance than the cross-pollinated species. For this reason improvement in self-pollinated forages has been limited to relatively few species, such as the lespedezas, vetches, and cowpeas."

POEHLMAN
Breeding Field Crops 1959 (8)

"The annual, self-pollinated forage species are limited in number and are minor in importance compared to cross pollinated species. For these reasons they have received less attention."

POEHLMAN
Breeding Field Crops (2nd Ed.) 1979 (9)

With these thoughts by Dr. Poehlman we might ask why even worry about breeding techniques with self-pollinated forages. The answer I think may lie in part with rejecting the above assumption. Granted alfalfa, white clover and red clover have probably been the most worked on and utilized of the forage legumes to this point in time, but crops such as subclover, *Aeschynomene*, *Stylosanthes*, and leucaena probably have potential for expansion to more acres than the cross pollinated legumes, especially in the southeastern U.S. In Louisiana and Florida the seed sales of these self-pollinated crops is eclipsing that of the cross pollinated species and self pollinated seed sales are not far behind in Arkansas and Alabama where Lespedeza and vetches are also important.

However, deciding that self-pollinated forages are worthy of a breeding effort is only the first hurdle to overcome as a breeder. It is easy to say that one will use any of the many techniques developed by breeders of self-pollinated row-crops. The application of these techniques is not as easy. Self-pollinated breeding-theory is based on recombination following crossing whether a backcross, pedigree, mass selection, single-seed descent or alternative technique is utilized. Yet this has been the major stumbling block for previous self-pollinated breeding efforts. There are two basic reasons for this: 1) the botany including taxonomy of these crops is poorly understood; 2) the crops by their very nature (forages) frequently set a small percentage of flowers even when they have not been manipulated to emasculate them and cross them.

Subterranean clover has received the most effort of the self-pollinated forages (10) and has been separated into three species based on crossing barriers (*T. subteraneum* L., *T. yanninicum* Katzn. and Morley an *T. brachycalycinum* Katzn. and Morley) (6). It appears that *Desmodium* spp. and *Stylosanthes* spp. may have many similar groupings (K. H. Quesenberry and J. B. Brolmann, personal communication) and the entire classification of *Alysicarpus* spp. has recently been reworked (4). Quesenberry and Deren have identified *Aeschynomene americana* crosses that produce seed, but the F_1 plants all die at approximately the third true- leaf stage (K. H. Quesenberry personal communication). Common alyceclover is a typical example of the problem with poor seed set. For every two flowers produced only one pod is made under natural conditions (11). Attempting crosses without emasculation resulted in over 70% of the flowers aborting and when emasculation was attempted 100% of the flowers aborted (11). Subsequent work has indicated that all seed set were selfs. All currently available alyceclover and aeschynomene seed comes from new or old collections of local strains or plant introductions. Hardy and Quesenberry have developed crossing techniques for *Aeschynomene* (5). Brolmann has developed techniques for *Phaseolus* and *Centrosema* but has not gone further as adequate variation exists in P.I. material (2). The majority of subclover cultivars also come from new and old collections of local strains (6). Kobe, a cultivar of common lespedeza, was a direct introduction from Japan. 'Climax' a variety of Korean lespedeza (*L. stipulacea*), originated as a selection out of an introduction from China. 'Rowan' originated from a single plant selection out of Korean lespedeza(9).

The difficulty of making crosses in these crops may be readily overcome as the botany of the crops is better understood (12). The inability to readily make crosses has perhaps not been a serious limit to the breeder up to this point as so much variation did exist in local strains and plant introductions, but further progress in most is dependent upon recombining some of the favorable traits now identified into a single cultivar. Selection of good parents for crossing is an important phase and must not be overlooked or P.I.'s will be brought in that are better than our improved cultivars.

This brings us to the next problem facing a self-pollinated-forage breeder. What is the genetic make up of a desirable self-pollinated-forage cultivar? Should it be heterogeneous and homozygous, or homogeneous and homozygous? Especially with perennial forages the question of the role of heterogeneity in disease and insect resistance becomes important. The current seed laws including the P.V.P. are certainly easier to invoke on homozygous

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homogeneous cultivars than on alternatives, but that doesn't mean that they are the best perennial forage cultivars. Perhaps this can be avoided by applying for P.V.P. of component lines and releasing a multiline cultivar. This issue is important because it has such a large impact on how early testing can and should be initiated in the program.

The Australian subterranean clover breeding program (3, 7) has been directed toward a homozygous and homogeneous cultivar. It has been based on a five stage testing program initiated at homozygosity, with initial characterization for maturity, hard seededness, formononetin content and other readily measured characters. Stage 2 looks at similar characters, but in alternative environments, Stage 3 evaluates disease and insect resistance and Stage 4 and 5 are field tests where defoliation effects and persistence characters are measured. A maximum of 10 lines make it to Stage 5 in each cycle. This program has resulted in the release of several new cultivars in Australia.

We have skipped from producing the F1 to homozygosity. My interviews with current self-pollinated-forage breeders including J.A. Mosjidis (Lespedezas), Ann Marie Thro (Aeschynomene, Stylosanthes), K. H. Quesenberry (Aeschynomene, Desmodium), J. B. Brolmann (Stylosanthes), Homer Wells (Lupine), G. R. Smith (Trifolium hirtum) and G. M. Prine (Cajanus cajun) indicate that this area has probably not received adequate attention because of the limited number of crosses made. Lupine breeding at Tifton, Georgia has utilized a pedigree selection program for gray leaf spot resistance, cold tolerance, bitterness and virus resistance (H. Wells personal communication). This is similar to programs on cowpeas, peanuts and soybeans which like lupine have potential uses other than forage and have relatively large flowers.

Quesenberry has initiated a pedigree program for both Desmodium and Aeschynomene, but this program has not yet completed a breeding cycle.

Brolmann has utilized a pedigree system to evaluate naturally occurring crosses in Stylosanthes spp. (personal communication). This is based on outcrossing percentages of nearly 10% at Fort Pierce, Fl compared with less than 1% in Australia (1). He considers his end product to be a population that is less than homogeneous and homozygous, but uniform for important traits.

It appears that this is an area ripe for investigation as crossing capabilities improve. Unfortunately, the pedigree system is based on the idea that 1 plant produces 1-3 rows etc. Most forage legumes are grown as mixed swords and the limited quantities of seed early in the program are not conducive to such evaluations. Forage yields are also destructive as far as additional seed increase is concerned. Producing adequate seed for evaluation under grazing is an extremely time consuming and expensive operation. Evaluating specific traits such as disease and insect resistance works well, but produces many lines which are intolerant of grazing. The pedigree system because of its advantages in genetic studies will continue to be heavily utilized by self-pollinated forage legume breeders.

Single-seed descent has many appealing characteristics to the forage breeder including 1) rapid advance to homozygosity, 2) use of greenhouse or seed production locations for growth without testing, 3) limited manpower requirements in steps prior to homozygosity. It however, requires modification for use by most forage legume breeders as most forage legumes produce less than one plant per seed, and some, such as alyceclover and desmodium may not even produce one plant for every two seeds. The single seed descent can easily be modified to take 1 pod (or a half dozen seed).

Mass selection has certainly worked well in the past providing the local ecotypes and plant introductions that have been so valuable in selection programs. It does not, however, take the greatest advantage of a small number of crosses and that is more than likely what the self-pollinated forage legume breeder will have to work with.

In summary the major challenge of self-pollinated breeders is to develop a better understanding of their crops. This will lead to improved crossing capabilities and open the door for much needed research on breeeding techniques.

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TANNINS IN FORAGE LEGUMES AND IMPLICATIONS FOR A BREEDING PROGRAM

K. H. Quesenberry[1]

INTRODUCTION

The use of plant derived tannins for leather making is recorded as early as 1500 B.C. (Haslam, 1966). Thus the existence of tannin compounds has long been known to man. In addition to this use in the leather industry tannins have other industrial uses including use in inks, plastics and dyes. In fodder plants tannins have been regarded as desirable (for possible protection against bird, insect and disease attack and against bloat in grazing animals) or as undesirable (because of their adverse affects on animal acceptance and/or digestibility).

VARIABILITY IN PLANT TANNIN TYPE AND CONTENT

As cited by Halsam (1966), the most widely accepted classification of vegetable tannins is that by Freundenberg who divided them into condensed tannins (those which do not readily break down under acid hydrolysis) and hydrolyzable tannins (those which have a polyester structure readily hydrolysed by acids. The principal forage tannins are of the condensed type (McLeod, 1974). Sarkar, et al., (1976) further divided the condensed tannins into proanthocyanidins (flavan-3-ol polymers) and leucoanthocyanidins (flavan-3,4-diol polymers) (Fig. 1).

Figure 1. Classification of tannins and their monomer units. (After Sarkar et al., (1976)

- TANNINS
  - FLAVOLANS (Condensed tannins) (flavanol polymers)
    - PROANTHOCYANIDINS (polymers of flavan-3-ols)
      - FLAVAN-3-OLS
        catechin
        epicatechin
        gallocetechin
        epigallocatechin
    - LEUCOANTHOCYANIDINS (polymers of flavan-3,4-diols)
  - HYDROLYZABLE TANNINS (esters of sugars and gallic acid)

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Most researchers agree that the main pathway for formation of condensed tannins is through polymerization of leucoanthocyanidins either alone or in conjunction with other flavanoids such as catechins (McLeod, 1974). Tannins are only a fraction of the polyphenols present in plants and much of the data on the occurrence of tannins in plants is questionable because it is based on non-specific methods of identification. Further, several investigators (Bate-Smith, 1973; Donnelly and Anthony, 1973; and Quesenberry and Albrecht, 1987) have shown that tannin content may vary within the plant with young leaves having higher content than older leaves and leaves having a higher percentage than stems. Tannins are generally thought to be sequestered in vacuoles within the plant cells.

Although the above variability in tannin content among maturity stages and tissue types is known to exist, major differences among and within forage plant species have been identified. Table 1 summarizes tannin content of various forage legume genera as reported in several references. Some genera such as _Glycine_, _Trigonella_, and _Vicia_ had no species with tannins while other genera such as _Astragalus_, _Medicago_, and _Trifolium_ had some tannin containing species and others without tannins. All species examined of a third group of genera including _Desmodium_ and _Onobrychis_ contained tannins. Methods used to obtain the data summarized in this table varied among researchers and only a limited number of species were sampled for some genera.

Table 1. Tannin content of various forage legume genera.

Genera	Tannin+	Reference
Astragalus	V	Davis, 1973
Coronilla	+	Marshall et al., 1979
Desmodium	+	Rotar, 1965
Doryvnium	+	Marshall et al., 1979
Glycine	-	Marshall et al., 1979
Indigofera	+	Marshall et al., 1979
Lotus	+	Foo et al., 1982
Lathyrus	V	Marshall et al., 1979
Lespedeza	+	Stitt, 1943
Lupinus	-	Marshall et al., 1979
Medicago	V	Marshall et al., 1979
Onobrychis	+	Marshall et al., 1979
Trifolium	V	Marshall et al., 1979
Trigonella	-	Marshall et al., 1979
Vicia	-	Marshall et al., 1979

+V = species within genera vary for presence or absence of tannin, + = all species reported in genera contain tannin, - = no species reported contained tannin.

Marshall, et al. (1979) reported the results of screening a large number of _Trifolium_ spp. for tannin content. Pandey (1971) also reported screening 30 species of _Trifolium_ for tannin content. Table 2 identifies _Trifolium_ spp.

which have been reported to contain tannins. Others such as Davis (1973) and Rotar (1965) have screened large collections of Astragalus and Desmodium spp., respectively, for tannin content.

Table 2. Trifolium spp. containing tannins +

Species	Reference
T. alpestre ‡	Pandey, 1971
T. arvense	Sarkar et al., 1976; Pandey, 1971
T. campestre	Sarkar et al., 1976; Marshall et al., 1979
T. dubium	Sarkar et al., 1976; Marshall et al., 1979
T. hohenackeri	Pandey, 1971
T. rubens ‡	Pandey, 1971
T. trichocephalum ‡	Pandey, 1971

+ Over 60 other Trifolium species reported to not contain tannins.
‡ Tannins only found in a few plants and only under water stress conditions.

METHODS FOR QUANTIFICATION OF TANNINS

Vanillin HCl Method

The vanillin HCl method of Burns (1963) or some modification of it have been the preferred rapid screening method for determining tannin content. Maxon and Rooney (1972) modified this procedure to include 1% concentrated HCl in the methanol extract rather than pure methanol. Walton et al., (1983) showed that either of the above procedures could give false positives with sorghum [Sorghum bicolor (L.)Moench.] and recommended a chloroform-HCl modification to remove the chlorophyll from the extract. They pointed out that sorghum forage extracted with methanol-HCl with or without vanillin added developed red color. They suggest that this color reaction is characteristic of leucoauthocyanidins. Subtracting the color in methanol-HCl blanks without vanillin could lead to the conclusion that the plant has no tannin like substances, and use of uncorrected values might lead to the conclusion that the plant has high levels of condensed proanthocyanidins.

Chromatographic and Other Techniques

Sakar et al. (1976) have described chromatographic techniques to further characterize plant tannins. Additional characterization techniques using NMR and other techniques have been used by Foo et al. (1982) to study tannin polymers. In general these techniques do not seem to be adapted to the large numbers and rapid time schedule needed by breeders in a screening technique.

Protein Precipitation Techniques

Hagerman and Butler (1978) have investigated various protein precipitation methods for quantifying tannin content of plants. Quesenberry and Albrecht (1987) reported the use of one such technique to determine the tannin levels in a group of Desmodium spp. They showed that laboratory run to run variability of the procedure was low. Immature leaves were higher in tannin than the first fully expanded leaf or mature leaves. Mature stems and petioles had the lowest tannin content. They reported tannic acid equivalents (TAE) in D. heterocarpon ranging from 115 to 51g kg^{-1} and a mean TAE content of D. uncinatum and D. intortum of 82 and 75 g kg^{-1}, respectively. This technique has many of the features of the vanillin-HCl procedure and may be more repeatable. Further work is needed to correlate these results with the vanillin-HCl procedure on a range of species and to correlate tannin levels measured by all these techniques with changes in animal digestive behavior.

BREEDING FOR ALTERED TANNIN LEVELS

As indicated in the introduction tannins as components of forage plants may have both beneficial and harmful affects. Much of the germplasm evaluation research carried out in the genera Medicago and Trifolium has been for the purpose of identifying species with tannins. The desired objective then being to transfer this characteristic into species of these genera which are of agronomic importance, but which have potential for causing bloat in grazing livestock. Although species have been identified which contain tannins, no success has been achieved in transferring this characteristic to alfalfa or any of the clovers of agronomic importance. This research has shown that the bloat safe characteristic of sanfoin (Onobychis viciifolia Scop.) and several Lotus spp. can be attributed to the presence of condensed tannins. Since the biochemical pathway for synthesis of tannins is complex, if appears unlikely that a single gene trait will be identified which is amenable to genetic transformation techniques. Thus the possibility of breeding for increased tannin levels in temperate legume species which do not exhibit naturally occurring tannins may be limited.

The most well characterized program of selection for decreased tannin levels in forage legumes is that of sericea lespedeza [Lespedeza cuneata (Dum. de Caours.) G. Don] carried out primarily by Donnelly and co-workers at Auburn University. Early research by Donnelly (1954) showed a high correlation of cattle grazing preference with fine stems and low tannin content. Bates and Henson (1955) studied the inheritance of tannin content in sericea and estimated heritability values of from 34 to 43%. Using a formula suggested by Wright, they also estimated that gene number involved in tannin inheritance was

19 to 24. In a later study Cope (1962) estimated the heritability of tannin content to be 71%. He noted a correlation of from 0.29 to 0.53 of tannin content with yield, but suggested that this relationship was largely a developmental phenomenon related to plant maturity. Donnelly (1959) studied season and maturity effects on tannin content of sericea and found that tannin content increased as temperature increased and precipitation decreased. Tannin content also increased with plant maturity. These reports suggested that rapid progress should be possible in selecting for decreased tannin content in sericea, but that precautions would be required related to the seasonal changes in tannin content and to avoid decreased yield when selecting for decreased tannin.

A major concern in the program of selection for decreased tannin in sericea was determination of the effects on dry matter digestibility (DMD) and subsequent animal performance. Donnelly and Anthony (1970) found a 23% increase in DMD (56% to 69%) of low tannin lines compared to high tannin lines. In further studies Donnelly et al. (1971) found that decreased tannin levels resulted in improved digestible dry matter intake of grazing animals. This study was complicated by the fact that the low tannin lines used had less vigor and did not produce sufficient forage for selective grazing. This result gave emphasis to the need to select for high yield while selecting for low tannin content. Donnelly and Anthony (1973) also showed that breeding sericea low in tannin concentration not only increased digestibility of dry matter and crude protein (CP) but that it also increased the CP of the plant. They further suggested that breeding low-tannin sericea with a high percentage of leaves would lead to a greater improvement than breeding for low tannin alone.

The culmination of this research was the release in 1980 of AU Lotan sericea (Donnelly, 1981). This variety was also selected for resistance to root-knot nematodes. Donnelly points out that most low-tannin plants in the breeding program to develop AU Lotan were severely damaged by a foliar disease caused by Rhizoctonia spp. and thus an additional objective became selection for resistance to this pathogen. This finding further bears out the fact that tannins may be both beneficial and harmful aspects of plants. When Mosjidis and Donnelly (1986) compared nine lines low in tannin to Serela (a high tannin cultivar), they found selection for low tannin had resulted in slightly reduced stem length, leaf weight and leafiness. Thus a larger portion of the dry matter of low-tannin lines consisted of stems. These efforts of breeding for decreased tannin content in sericea emphasize that any program of selection for altered tannin content must constantly monitor the effects on related plant characteristics to avoid selection for correlated traits which are undesirable.

SUMMARY

Forage legume genera show quantitative and qualitative variability in tannin content. Several related but different polyphenolic compounds often are lumped together under the general term tannins and this may contribute to different experimental findings concerning the detrimental or beneficial properties of tannins. The commonly used vanillin-HCl procedure is well suited for breeding and selection research, but does not distinguish between different types of tannins. Other techniques which do separate tannin types may be too slow for a breeding program. The protein precipitation technique requires further research.

Although some tannin containing species have been identified in Trifolium and Medicago, to date increased tannin has not been transferred to cultivated alfalfa or any of the cultivated clovers such as red, white, crimson, or sub. Genetic selection for decreased tannin was successful in sericea lespedeza, but low-tannin lines were usually lower in total dry matter yield than the best high-tannin lines. Tannin content has generally been shown to be a moderately highly heritable trait which can be altered dramatically by selection. Selection programs must account for tannin differences: a) among plant parts, b) due to maturity differences, c) related to environmental stress, and d) among plants. Such selection research must also continue to work against the positive correlation of yield and tannin content. Additional research is needed to establish threshold levels below which tannins have little effect on forage digestibility. Research is also needed to correlate levels of "tannins" or isolated specific polyphenolic compounds as measured by various procedures with changes in animal digestive behavior. The prospects of improved animal performance related to selection for altered tannin levels in forage legumes appear to be good.

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HISTORY OF COOL SEASON GRASS BREEDING IN THE SOUTHEAST

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Plant breeding is a process of plant improvement involving active human involvement. As such, the history of cool season grass breeding in the southeast region is a history of scientists and their contributions to pasture and forage crop improvement. This review will highlight the contributions of many of these scientists. I must confess that I worked under a considerable handicap while researching this history. I was born in 1954. My first exposure to most of the individuals and crops discussed in this review was in the 1980's. I am forced to rely on the literature and on the memories of many who contributed far more to this history than I. To all those who responded to my telephone requests for materials and information, many thanks.

Relatively few cool season forage grass species have been researched and exploited successfully in the southeast region. These are limited to tall fescue (Festuca arundinacea Schreb.) annual ryegrass (Lolium multiflorum Lam.), orchardgrass (Dactylis glomerata L.), timothy (Phleum pratense L.), Kentucky bluegrass (Poa pratensis L.), and Phalaris aquaticus L. Cereal crops utilized as winter forage contribute significantly to winter grazing in the southeast region, but most were developed for grain production and will not be discussed.

I would like to digress for a moment and discuss breeding methodology. Plant breeding has two basic elements, identifying superior gene combinations and capturing superior gene combinations. The discovery, increase, and marketing of superior populations as cultivars certainly is a valid breeding method, and will be a recurring theme in this review. Such methodology does not always appear to be "plant breeding" to the lay public, and even to some agronomists. After all, no hand crosses are made. However, this methodology was, and continues to be a valid breeding approach in crops or regions where little genetic improvement has been achieved.

Although tall fescue was introduced to the region sometime prior to 1900, the recorded history of tall fescue begins in 1931 with the discovery of 'Kentucky 31' by E. N. Fergus (Fergus and Buckner, 1972). It is an adapted ecotype that probably makes up the bulk of the 35 million reported acres (Buckner et al.,1979) grown in the United States to this day.

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Tall fescue was productive, persistent, and widely adapted, but cattle performance was mysteriously poor on the species. The USDA-ARS program headed by R. C. Buckner at the University of Kentucky began addressing this problem in the late 1950's by developing inbred lines and evaluating them for palatability to cattle in cafeteria-style comparisons. 'Kenwell', the end product of this program, was released in 1965 and was shown to be significantly more palatable than Kentucky 31 (Buckner and Burrus, 1968), but was not shown to offer any advantage over Kentucky 31 in subsequent grazing trials (Buckner, 1973).

Buckner also initiated a program involving crosses of tall fescue with annual ryegrass, perennial ryegrass (Lolium perene L.), and giant fescue (Festuca gigantea (L.) Vill.) in the early 1960's to improve the forage quality of tall fescue. 'Kenhy', released in 1976, was the first cultivar developed from this endeavor, and does exhibit improved quality when graded by laboratory measures (Buckner et al., 1977). However, the animal problems were not yet solved. 'Johnstone', released in 1981 (Buckner et al., 1983) is another cultivar originating from this program. Johnstone tall fescue may give superior animal performance, but its enhanced quality was not the primary cause of the observed increase in animal performance.

The real breakthrough in tall fescue improvement was made in the early 1970's, and not by plant breeders. The discovery of Acremonium coenophialum Morgan-Jones and Gams (previously identified as Epichloe typhina (Fr.) Tul.) in a tall fescue pasture with a history of poor cattle performance by C. W. Bacon (Bacon et al., 1977), and the subsequent comparison of cattle performance on A. coenophialum-infected and A. coenophialum-free tall fescue pastures by C. S. Hoveland (Hoveland et al., 1980), identified the fungus as the actual cause of poor cattle performance on tall fescue. Breeders now had another method for tall fescue improvement: elimination of this endophyte. Breeding objectives for improvements in characters other than forage quality also assumed new importance.

An Auburn University program initiated in the mid 1970's by R. L. Haaland, and continued in the 1980's by J. F. Pedersen had the objective of increasing winter productivity in tall fescue. Beginning with Mediterranean plant introduction materials, this program resulted in the release of 'AU Triumph', which was 80 % more winter productive than Kentucky 31 (Pedersen et al., 1983). As with Johnstone, it was released as a low A. coenophialum cultivar, although a low endophyte infection level was not an initial objective in the development of either of these popular cultivars. These two cultivars were the first of what has come to be known by some as the second generation tall fescues, or low endophyte tall fescues.

Continued selection for winter productivity by Pedersen has resulted in lines with winter productivity twofold that of AU Triumph, but which are quite susceptible to frost damage (unpublished data).

Other "new" breeding objectives in tall fescue focus largely on increasing its persistence and productivity in marginal areas of adaptation. This includes screening plant introduction accessions for adaptation to the southeast region by J. H. Bouton, resulting in the release of GaFes1 and GaFes2 tall fescue germplasms (Bouton and Powell, 1982), collection of ecotypes from south Georgia by Bouton and his work investigating incidence of rhizomes in tall fescue (D'Urva et al., 1983; and Jernstedt and Bouton, 1985). Collection and testing of superior ecotypes continues in Mississippi by C. E. Watson, while screening of plant introduction accessions and/or other populations proceeds in south Alabama (J. F. Pedersen) and central Florida (D. D. Baltensperger). Cultivar release from one or more of these programs appears imminent.

The most recent challenges for the tall fescue breeder are associated with possible losses in performance due to the elimination of A. coenophialum. Insect resistance due to A. coenophialum infection has been demonstrated in the laboratory (Siegel et al., 1987) and there has been one report of increased disease susceptibility in A. coenophialum-free tall fescue in the field (Bush and Burrus, 1988). Perhaps earlier work by C. D. Berry (1973) studying rust resistance will have renewed importance. A. coenophialum-free cultivars are perceived as having poorer seedling vigor by farmers, although this has not been documented by researchers. Susceptibility to plant parasitic nematodes has been shown to be higher in A. coenophialum free tall fescue (Pedersen et al., 1988). Indications of physiological advantages in A. coenophialum-infected tall fescue under drought conditions are beginning to appear in the literature (Belesky et al., 1987) Finally, J. C. Read and B. J. Camp (1986) have documented lack of stand survival in A. coenophialum-free tall fescue pastures, compared to A. coenophialum-infected tall fescue pastures in a Texas grazing study in a marginal environment.

Certainly tall fescue breeders in the southeast region are faced with more challenges now than before the A. coenophialum-tall fescue relationship was discovered. They also are privilege to more fundamental information regarding their crop than ever before. When the southeast region is considered as a whole, today's tall fescue breeding team includes breeders (Bouton, Pedersen, Rice, Van Santen, Watson, Wofford), a cytologist (Eizenga), a tissue culturist (Conger), and ready access to physiologists, pasture management scientists, animal scientists, pathologists, etc. throughout the area. With continued close cooperation and communication, our new challenges in tall fescue improvement should be met.

Next to tall fescue, annual ryegrass is probably the most important cool season species utilized in the southeast region. The first registered cultivar release was 'Gulf', from R. M. Weihing's program in 1958 (Weihing, 1963). Gulf was selected for early maturity and rust resistance from a Uruguay plant introduction accession. It is still widely used today, and is considered the standard by which to judge all other annual ryegrasses in this region. H. W. Bennett and H. W. Johnson released another rust resistant cultivar, 'Magnolia', in 1965 (Bennett and Johnson, 1968). It, however, has not seen widespread use. The most recent rust resistent annual ryegrass release is 'Florida 80'. It was selected from volunteer plants of several older cultivars and germplasms that had reseeded for two or more years in pastures in Florida and Georgia (Prine et al., 1986). The search for rust resistance in annual ryegrass was documented as early as 1956 by E. C. Holt (1956) in Texas and H. D. Wells (1956) in Georgia, and is not over. Active programs headed by G. M. Prine in Florida, C. E. Watson in Mississippi and L. R. Nelson in Texas are continuing to pursue this breeding objective.

One other cultivar, 'Marshall', released in Mississippi in 1980 (Arnold, et al., 1981) merits special mention. It is a cold-hardy annual ryegrass that was "the result of 29 years of natural selection from common ryegrass as a reseeding stand under grazing conditions" in north Mississippi. It could justly be called an adapted ecotype. It is also a very successful cultivar, already widely utilized in the region.

The other cool season grass species are not as broadly adapted to the entire region, and have not received as much research emphasis. Orchardgrass improvement for the South was the topic of a 1954 presentation to the Southern Pasture and Forage Improvement Conference (SPFCIC) by T. J. Smith (1954). More recently, orchardgrass breeding was continued in Virginia by L. Taylor, resulting in the release of 'Jackson' and 'Virginia 80'. R. C. Buckner collected "naturalized strains" of orchardgrass from fields across Kentucky, and selected a broad based population from these strains that was released as 'Boone' orchardgrass (Buckner, 1963). McClain, in South Carolina, released 'Piedmont' orchardgrass in 1978. It is a four clone synthetic exhibiting high yield, late maturity and rust resistance (McClain, 1986).

'Clair' timothy, and 'Kenblue' Kentucky bluegrass, are the only registered cultivars of these two species developed in the southeastern region. Clair is an adapted ecotype collected in Indiana and released in 1962 (Buckner,1962). It continues to be a popular variety as evidenced by continuing requests for foundation class seed. Kenblue Kentucky bluegrass is a blend of seed from old (circa 1955) seedfields located in central Kentucky (Buckner, 1968). A Kentucky bluegrass population probably dating to

the early 1800's was collected in Virginia by L. Taylor and T. H. Taylor and released as 'Piedmont' Kentucky bluegrass, but seed has not been successfully increased.

One other cool season grass species, Phalaris aquaticus L., has seen breeding effort in the southeastern region. 'Evergreen', developed by E. C. Holt in Texas, and 'AU Oasis', developed in Alabama in program initiated by C. D. Berry, continued by R. L. Haaland, and completed by J. F. Pedersen (Pedersen, et al., 1983) have merit as improved forages, but have not been utilized by the forage industry to date. Seed production problems have plagued the AU Oasis marketing effort, reminding us that if our product is to be of worth to farmers, we must be able to produce seed.

A history of cool season grass breeding in the southeastern region would not be complete without mention of the concept of exclusive marketing of publicly developed cultivars by private industry. The general argument supporting such a relationship centers on the need for expert seed production and marketing of forage crops, combined with relatively low seed volume and the need for profit by the seedsman. This relationship was discussed in depth at an earlier SPFCIC meeting (Campbell, 1985; Elsner, 1985; Hanna, 1985; Nelson, 1985; Pedersen, 1985), and will not be discussed further here.

In closing, I must state that although I have confined my discussion to breeders of the southeast region, public breeders, private breeders, and private enterprise outside this region have had considerable direct impact on our forage history. This history is in no way intended to detract from their contributions of cultivars, technology, seed production, and marketing expertise, or the outstanding cooperation in breeding efforts throughout the entire forage industry.

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FORAGE GERMPLASM EVALUATION

M.A. Hussey and D.I. Bransby [1]

INTRODUCTION

The ultimate goal of a pasture improvement program is to provide "improved" forage cultivars to farmers and ranchers. While the final evaluation of a new species or cultivar must be in an environment similar to where it will be utilized, it is not possible to evaluate all hybrids under every possible combination of fertility, soils, and management. To facilitate the selection of "superior" germplasm, uniform evaluation procedures are utilized.

According to Jones and Walker (1983) "there have been no major new breakthroughs in the accepted theoretical procedures for the evaluation of pasture plants." They continued by stating that "except under circumstances which require special strategies, there are no clear shortcuts in establishing the suitability of plants for the soil-plant-animal complex encountered in the field." Therefore, due to the complexity of forage crop production systems, a detailed multi-location, multi-year, multi-disciplinary evaluation procedure is utilized with a grazing evaluation considered essential prior to the final release of a cultivar (Hoveland, 1979; Mochrie et al., 1981).

Specific methodology for the evaluation of forage crops has been covered in detail by speakers at past meetings of the Southern Pasture and Forage Crops Improvement Conference (SPFCIC) Breeders Workgroup (Quesenberry et al. 1977; Burton and Monson, 1979; Coleman 1979; Haaland, 1979; Hoveland, 1979; Quesenberry, 1980; Burton, 1982; Riewe, 1982; Lippke, 1983; Sleper et al., 1983) as well as in several excellent reviews (Mochrie et al., 1981; Jones and Walker, 1983; Mott and Moore, 1985). An overview of such an evaluation plan from Jones and Walker (1983) is presented in Table 1. We do not wish to discuss forage evaluation methodology in detail, but rather point to selected evaluation techniques which may facilitate the overall evaluation of forage germplasm.

SPACED PLANT NURSERY

The spaced plant nursery is utilized to determine the overall adaptation of a new species or hybrid. The initial identification of a superior genotype occurs in such a nursery, so techniques are required that allow the breeder to rapidly and accurately evaluate large numbers of plants.

FORAGE YIELD

Forage yield, particularly when averaged over several locations, or in response to a management stress such as clipping is a common method for determining the adaptation of a genotype. In the initial stages (spaced plant nursery) of evaluation, yield estimates are generally made by a visual appraisal of vegetative vigor. Yield estimates from small plots generally are obtained by harvesting small quadrats or specially designed forage plot harvesters (Frame, 1981).

The use of double-sampling techniques represents one method of predicting forage yield which may reduce the time required to quantify herbage mass. Peterson (1988) compared the use of plant height, the disk meter, and the single probe capacitance meter for estimating forage yield. Results from this study indicated that all techniques were effective in estimating forage yield in small plots but that plant height and the disk meter were influenced by season within a year therefore, requiring separate calibration equations to be developed. Peterson and Hussey (1987) have also shown significant cultivar effects for plant height-yield and disk meter-yield relationships, suggesting that caution may be required when using double-sampling techniques for the evaluation of genotypes with a diverse range of growth habits.

LEAFINESS

Since livestock have the ability to select a large percentage of leaf in their diets (Laredo and Minson, 1973), and because leaf blades generally are of higher nutritive value than the stem component, increasing the relative leaf to stem ratio of a cultivar should result in greater animal gains. To date, few attempts have been made to select for improved leaf to stem ratio although, dwarf genotypes of pearl millet (Burton, 1982), have been shown to result in enhanced animal performance when compared to tall cultivars, even though they produce less forage.

Most studies which have attempted to determine variation in the relative leaf content of forage have utilized either visual estimates of leafiness or tedious hand separations of leaf and stem. Holt (1963) in one of the few studies which compared visual estimates of leaf with hand separated estimates reported that visual estimates of leafiness were more closely related to tiller density than to leaf content of the forage,

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making visual assessments of leaf content of relatively little value.

Recently, the use of near infrared reflectance spectroscopy (NIRS) has been investigated for its potential of estimating leaf content of forage (Hill et al., 1988). They concluded that NIRS was an effective tool for estimating the leaf content of alfalfa in both plots and in the diets of livestock. Studies with bermudagrass (Peterson, 1988) have also confirmed the potential of NIRS for predicting leaf content of warm-season grasses.

FORAGE QUALITY

The ability to rapidly evaluate forage digestibility _in vitro_ (IVDMD), is an extremely important analytical tool in plant breeding. Most reviews on forage evaluation techniques, consider an estimate of forage digestibility an essential step to the evaluation of spaced plant nurseries. Selection for greater IVDMD has resulted in the release of several bermudagrass cultivars with improved digestibility and enhanced animal performance (Holt et al., 1983, Eichhorn et al., 1986). In the past 10 years, NIRS has shown to accurately predict forage IVDMD, CP, etc. when properly calibrated (Barton and Burdick, 1981, Jones et al., 1987). The major limitation to the use of NIRS technology appears to be the high initial cost of the instrumentation and the lack of adequate calibration sets for warm-season forages.

The use of high activity fungal cellulase enzymes is another technique which may be utilized to estimate forage nutritive value. While commercial cellulase enzymes were originally tried in the early 1960's as a replacement for rumen fluid, it was not until the early 1970's that enzymes were identified which could adequately replace rumen fluid (Jones and Hayward, 1973). Several commercial sources of cellulase have been evaluated (Gabrielson, 1986). A comparison of NOVO celluclast and a standard _in vitro_ assay indicated that both techniques were equally effective for ranking warm-season perennial grasses (Stair et al., 1987).

SMALL PLOT EVALUATIONS

Small plots, evaluated at multiple locations are essential to determining the adaptation of germplasm. For many species, small plot evaluations are conducted for 2-3 years in which multiple clipping heights and/or frequencies are utilized. Past experience with bermudagrass small plot evaluations has indicated that a minimum of 4 years (including the establishment year) are required at each location to obtain an accurate reading of cultivar performance (Conrad, Holt, and Taliaferro, personnel communication).

Multiple clipping heights and/or frequencies are often imposed on small plot evaluations to identify superior germplasm. Such tests may be quite effective in determining the relative persistence of diverse germplasm (Jones, 1974), or may contribute relatively little information, depending on the growth form of the species under evaluation. For instance, multiple clipping frequency-clipping height experiments conducted with a flail type mower, failed to give differences in relative persistence for bermudagrass (Holt, personnel communication), while tiller density was significantly reduced when harvested to ground level with electric clippers. These results suggest that while differential cutting heights may separate germplasm, certain species may require more intensive defoliation than can be obtained with standard forage harvesting equipment.

Many new forage cultivars fail because of their poor adaptation. To prevent this, proper selection of test sites is required. To properly select test sites, an agroclimatic approach similar to that proposed by Nix (1982) in Australia may be utilized. Such a classification system, groups similar climatic zones based on differences in a number of climatic variables, particularly rainfall, ET, temperature, etc. In the United States, many evaluation locations are determined by the presence of a research location. We have found, that cooperative efforts involving the USDA-ARS, USDA-SCS, seed companies, and producers has greatly expanded our ability to evaluate germplasm for wide adaptation.

GRAZING EVALUATIONS

The final evaluation of forage cultivars must be conducted using the grazing animal if the the cultivar is to be utilized for pasture. While clipping can determine the ability of a plant to withstand defoliation stress, it does not measure other effects associated with the grazing animal (treading, pulling, urine and dung, etc.) (Watkin and Clements, 1978). Most reviews on the evaluation of forage germplasm suggest that genotypes should be grazed as soon as possible (ie. spaced plants or small plots), however, due to logistical and financial constraints, grazing evaluations are generally conducted just prior to the release of a cultivar. In certain species, it may be possible to obtain a good estimate of persistence through the use of properly designed clipping trials (Jones and Walker, 1983), however, in grazing sensitive species such as alfalfa, grazing and clipping may give entirely different results. In crops such as this, direct

selection under grazing may be the best method for developing germplasm with tolerance to herbivory (Bouton, personnel communication, Bouton, 1988).

It is strongly recommended that the final evaluations of germplasm should be evaluated over a range of stocking rates or levels of available forage. Such an evaluation will provide useful animal data over a range of possible management alternatives, as well as determining the persistence of the cultivar. A single set stocking rate comparison of cultivars may lead to erroneous conclusions concerning the potential of a cultivar, since "optimal" stocking rates for maximal ADG's, do not always give maximal economic returns.

SUMMARY

The evaluation of forage germplasm prior to the release of a cultivar is a laborious and time consuming process. Improved efficiency can be obtained by the use of innovative plant breeding methods, such as restricted recurrent phenotypic selection, or by the development of new methodology to facilitate germplasm evaluation during each cycle of selection. Because quantitative characters such as forage IVDMD, persistence, winterhardiness, etc. are extremely important in determining the ultimate success of a cultivar, evaluations must be carried out over a range of environmental conditions. As has been pointed out by Jones and Walker (1983) there are not shortcuts in breeding forage cultivars, however, the adaptation of techniques to facilitate germplasm evaluation should improve the overall efficiency of forage breeding programs.

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TABLE 1 Generalized Plan for the Evaluation of Forage Germplasm[1]

STAGE I	Genotypes grown as spaced plants at 1-2 locations. Data is collected to determine general adaptation. Lines are eliminated based on forage production, IVDMD, winterhardiness, etc. Duration 1-2 years.
STAGE II	Small plot evaluations of selected lines from the Stage I evaluation. Genotypes eliminated based on performance under cutting. Plots may be subjected to grazing. Duration 2-3 years.
STAGE III	Superior genotypes from Stage II moved to larger plots or paddocks. Pastures subjected to grazing management at multiple stocking rates. Animal production measured. Lines eliminated based on persistence, animal performance, etc. Duration 2-5 years.

1 Adapted from Jones and Walker (1983)

ECOLOGY AND PHYSIOLOGY INFORMATION EXCHANGE GROUP

INFLUENCE OF THE FUNGAL ENDOPHYTE ON PHYSIOLOGY AND ECOLOGY OF TALL FESCUE

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Poor animal performance on tall fescue (Festuca arundinacea Screb.) is widespread and is associated with the fungal endophyte Acremonium coenophialum Morgan-Jones and Gams (Stuedemann and Hoveland, 1988). The vastly improved animal performance on low-endophyte tall fescue has encouraged release of endophyte-free cultivars which are being aggressively marketed. Techniques have been developed for destroying existing infested tall fescue sods and replanting with endophyte-free seed. Substantial acreages have been replanted and this trend is expected to continue. Surveys in Alabama show that endophyte-free acreage has increased by 130,000 acres from 1984 to 1987 (Ball, 1987). However, concern has been expressed by research and extension workers as to potential dangers in tolerance of endophyte-free tall fescue to environmental stress.

The popularity of tall fescue is a result of its wide adaptation, ease of establishment, long productive season, tolerance to grazing, drought, poor drainage, pests, and a wide range in soil pH (Burns and Chamblee, 1979). Most endophytic fungus-grass associations are mutualistic (Bacon, et al. 1986). This suggests that these fungi co-evolved with their grass host, are non-parasitic, and the endophyte-plant relationship is a mutualistic symbiosis (Siegel et al., 1987b; Bacon and Siegel, 1988). This raises the question of whether tall fescue, when free of the endophyte, continues to have the same productivity and persistence as infected grass in stressful environments (Siegel, et al. 1987a).

The fungus benefits from the association by receiving nutrients, protection, reproduction, and dissemination (Bacon and Siegel, 1988). In return, the plant may be aided by modified plant morphology, enhanced pest protection, growth stimulation, and greater tolerance to drought and grazing, resulting in better competition with other species in a pasture. This paper attempts to review some of the changes in or benefits to the tall fescue plant from the endophyte assocation.

PLANT RESPONSES TO THE ENDOPHYTE

Plant Morphology

Endophyte-infected (EI) cloned plants had thicker and narrower leaf blades than endophyte-free (EF) plants, and flooding, N rate, or drought stress did not appreciably alter this characteristic (Arechavaleta, 1987). The benefits of this morphological change are unknown, but it could contribute to plant water conservation and drought tolerance. Hill et al. (1987) reported that EI plants of two clones had more erect growth and crowns imbedded deeper in the soil than EF plants.

Maturation and Seed Development

A difference in ultrastructural morphology of mesophyll tissue of leaf sheaths was the earlier occurrence of air spaces in EI than EF plants; this difference disappearing as plants aged (Arechavaleta, 1987). This suggests that the endophyte may accelerate plant maturation rate. In the field, cloned material of EI plants produced seedheads up to 2 weeks earlier than EF plants (C. W. Bacon, unpublished). Similar results have been observed in the field on a number of clones (N. S. Hill, unpublished). Thus, the endophyte may interact with some developmental mechanism such as production of a growth regulator in the plant to alter growth processes.

In a comparison of Ky 31 tall fescue EI and EF plants grown from seed, EI plants produced up to twice the seed yield of EF plants (Clay, 1987). The genetic diversity of this cultivar limits the value of these results but research by Rice et al. (1987) in South Carolina with 20 clones showed EI plants had greater seed weight, more seeds, and more panicles per plant than EF plants. These results suggest that population shifts could occur over time by natural reseeding of mixed populations, increasing the level of infestation in a pasture.

Tiller Development

Tiller numbers were substantially greater on EI than EF plants when grown at a high N rate (Belesky et al. 1987a: Clay, 1987; Hill, et al. 1987). In another study, similar results were obtained with cloned plants at a high N rate but at low and medium N rates there was no difference in tillering of EI and EF plants (Arechavaleta, 1987). Tiller development is related to N rate but responses to the endophyte appear to differ among tall fescue clones.

Nutrients

Herbage production of cloned EF and EI plants were similar at low N levels but at higher rates the EI plants were 67% greater than EF plants (Arechavaleta, 1987). More efficient utilization of N may occur in EI than EF plants at higher N rates. Lyons (1985) found that EI and EF plants responded differently to N rates, and that as N rate increased, the glutamine synthetase activity of EI plants was greater. This was interpreted to represent

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in the blades of EI tall fescue, a C_3 plant that loses substantial amounts of NH_4^3 through photorespiration.

Uptake of minerals was generally unaffected by infection status of tall fescue except that EI clones were slightly higher in K and lower in B concentration (Wilkinson, 1987). One interesting finding was that although herbage growth was unaffected by infection status, root growth was significantly greater in EI than EF clones when grown in P deficient soil.

Herbage Yield

Herbage yields of EI plants have been substantially higher than EF plants of the same clone (Arechavaleta, 1987, 1987; Belesky, 1987a). However, this advantage is affected by N rate, drought stress, and individual clones. Hill et al. (1987) found no yield advantage in EI plants of five clones. In field trials where EI and EF Ky 31 tall fescue from seed have been compared, yield differences were small or non-existent (Pedersen et al., 1982; Siegel et al., 1987). The lack of yield response in seed-planted trials suggests that the genetic plasticity within a diverse cultivar such as Ky 31 tall fescue includes individuals which would not behave as a single infected clone and its noninfected ramet. The yield advantage of EI over EF plants of the same clone may be a result of higher photosynthetic rate (Belesky et al., 1987a). The endophyte may also alter growth processes by producing a growth regulator. Porter et al. (1985) found in vitro production of auxin by one endophyte, Balansia epichloe, but it is not known if this endophytic fungus can regulate plant growth. In perennial ryegrass (Lolium perenne L.), gibberillin, which generally stimulates cell expansion, was considered a likely possibility for increasing yield of EI plants (Latch, et al. 1985).

Drought

Stand persistence of EF tall fescue was not a problem in a 4-year grazing trial on heavy clay soils in central Alabama (Hoveland et al. 1983). This has generally been the case except on coarser textured soils or under greater drought stress. This is illustrated by the results of Read and Camp (1986) in the lower rainfall Blacklands of Texas where EI tall fescue produced more herbage and had better drought survival than EF plants in a 3-year grazing trial. Severe droughts during the past several years in the southeastern states have resulted in stand losses of EF tall fescue, particularly when grazed closely in summer. When harvested every 3 weeks, EF Ky 31 and AU Triumph tall fescue stand losses were greater during two drought years when cut at a 1½-inch as compared to a 3-inch stubble (C. S. Hoveland, unpublished).

The mutualistic relationship of endophyte and plant which favors higher herbage production also occurred under mild moisture stress (0.05 MPa) in a study with individual clones (Arechavaleta, 1987). Under more severe moisture stress (-0.50 MPa) where no significant yield advantage occurred, 75% of the EF plants died and all EI plants survived. Belesky et al. (1986b) reported that EI clones responded to decreased water availability by limiting growth while EF clones continued to grow for a time at rates similar to non-limiting conditions. White and Comeau (1987) reported that EI plants had lower CO_2 exchange and transpiration than EF plants of the same clone. In another clone, the endophyte had the opposite effect.

The superior drought tolerance of EI tall fescue plants would insure survival and improve their competitive ability under moisture stress in a pasture. Drought tolerance may partially be a result of leaf rolling which is facilitated by narrower and thicker leaves of EI plants. Increased leaf rolling was observed for EI plants under drought stress (Arechavaleta, 1987). Rolling is an adaptive mechanism that reduces effective leaf area and hence the amount of heat that strikes that area (Parsons, 1982). The difference in stomatal resistance in EI plants relative to EF plants reported by Belesky et al. (1987) is also indicative of a drought tolerance mechanism.

Grazing tolerance

It is often suggested that a beneficial effect of the endophyte on tall fescue persistence is reduced palatability and thus less plant stress from overgrazing (Bacon and Siegel, 1988). The lower grazing pressure on EI as compared to EF pastures may be a result of lower intake and animals spending more time in the shade because of intolerance to heat when afflicted with fescue toxicosis (Stuedemann and Hoveland, 1988). Results of a grazing preference trial with EI and EF space plants in South Carolina furnished no evidence of a significant preference for EF plants (Chrestman et al., 1987).

Plant Pathogens

Various endophytic fungi infecting Festuca species have been shown to cause in vitro inhibition of several grass pathogens (White and Cole, 1985, 1986). However, this reviewer is not aware of any published or unpublished evidence of improved disease resistance in EI tall fescue grown in the field.

Insects

There is strong evidence that EF tall fescue is more susceptible than EI grass to attack

by several insect species. In a review by Bacon and Siegel (1988), endophytes were involved in tall fescue resistance to attack by Argentine stem weevil, fall armyworm, house cricket, oat birdcherry aphid, greenbug aphid, and milkweed bug. Jessup tall fescue seeded into bahiagrass (Paspalum notatum Flügge) sod in south Georgia was severely damaged by crickets on EF plots while EI plots were unaffected (J. H. Bouton, personal communication).

Nematodes

Nematodes were shown to adversely affect persistence and productivity of tall fescue in sandy Coastal Plain soils (Hoveland et al., 1975). Plant parasitic nematodes reduced forage and root growth of large-rooted much more than small-rooted genotypes (Elkins et al., 1979). However, since the endophyte infection status of plants in this study was not known, one can not be sure that root size was the determining factor. In a recent Alabama study by Pedersen et al. (1988), soil and root nematode populations were much lower on EI than EF plants. In an Arkansas field study, EF tall fescue was more severely drought stressed than EI grass as indicated by higher canopy temperature (West, 1987). Nematode populations were substantially higher in EF than EI tall fescue. The severe stand losses reported by Joost (1987) in Louisiana on EF as compared to good persistence on EI tall fescue of GA 5 and Ky 31 cultivars may be related to nematode resistance. If these results are confirmed, it may require that EI tall fescue be used if this grass is to be grown on sandy Coastal Plain soils.

CONCLUSIONS

The benefits to enhanced animal performance with EF tall fescue has encouraged destruction of EI pastures and replanting with EF seed. However, increasing evidence indicates that the endophyte may have beneficial effects on the host plant in respect to plant morphology, nutrient responses, herbage yield, drought tolerance, and insect and nematode tolerance. These factors may contribute to plant persistence, competition with weeds and warm season perennial grasses, and tolerance to abusive grazing practices. Genetic variation among tall fescue clones in relation to the endophyte indicate that the relationship is complex and deserves much study. However, it is certain that the tall fescue-endophyte is one of mutualistic symbiosis.

Since the endophyte benefits the tall fescue plant in a number of ways, the question must be asked about the wisdom of replanting infested pastures with EF seed. In the extreme lower part of the tall fescue belt where environmental stresses are greatest and warm season perennial grasses are an important component in swards, the dilution effect in animal diets may allow EI grass to be used successfully. Likewise, where legumes are maintained in tall fescue, EI grass may be satisfactory for certain classes of livestock. However, where tall fescue is the sole component in a pasture and high rates of N are applied (such as in broiler-producing areas) it would appear best to replant with EF seed. Even if stands persist only 5 or 6 years, the enhanced animal performance is well worth the cost of replanting thinning stands. Present indications are that EF tall fescue is less tolerant of abuse in stressful environments. This suggests that grazing pressure on EF tall fescue should be reduced in summer, especially under drought conditions.

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THE ECOLOGY AND PHYSIOLOGY OF COOL-SEASON FORAGES UNDER INTENSIVE ROTATIONAL GRAZING SYSTEMS

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Development of simulation models of crops and pastures is a prequisite for the construction of models of grazing systems. The current rate of expansion of our knowledge base in the physiology of crop yield has been quite slow, perhaps as a consequence of a reductionist approach in the agricultural and biological sciences, and this has hindered the development of simulation models. Short-comings of models based on physiology have not restricted the march of computer-based technology into agriculture for expert systems models have replaced many of the complex ones and have also generated many new applications because of their versatility, low cost, and because most can function in personal computers. Models of grazing systems are complex because of the involvement of grazing animals, the number of plant species the complexities at the interfaces of soil, plant, animal and environment. One of the areas that we are not particularly well-versed is in the physiology of species and communities in grasslands as modified by grazing. Recent emphasis at the plant-animal interface has helped in the definition of the problem. Plants grown in communities (eg pastures) are different and react differently from plants that are grazed by herbivores. Parsons and Johnson (1986) also point out differences in physiological responses of grazed and cut swards.

A symposium in Australia in 1976 addressed many aspects of plant relations in pastures (Wilson 1978) while others in United Kingdom were concerned with sward composition and productivity (Charles and Haggar, 1979) and plant physiology and herbage production (Wright, 1981). More recent views were expressed in a volume of grazing published by British Grassland Society (Frame, 1986) and the proceedings of session dedicated to the plant-animal interface in grazing lands at the 15th International Grassland Congress in Japan in 1985 (Horn et al., 1987).

The following discussion is limited to physiological aspects of vegetative tillers of cool-season grasses.

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ENERGY RELATIONS

Defoliation by grazing impacts the energy balance of pastures with often negative effects on photosynthesis and growth largely because of reduction in photosynthetic surface area. Brown (1987) reviewed this area at this conference last year, however, light relations are critical to other reactions of swards to grazing that will be discussed subsequently.

The amount of energy absorbed by a pasture is represented by the following equation:

$$I_a = I_o - I_o e^{-kl} \qquad (1)$$

Where I_a = absorbed energy
I_o = incident energy
K = extinction coefficient
L = leaf area index

Defoliation of tillers by grazing drastically reduces leaf area index and, consequently, the amount of energy absorbed. Defoliation may also decrease the extinction coefficient through charges in canopy architecture. Since animals remove the younger upper canopy leaves that have higher photosynthetic efficiency, the efficiency of conversion of absorbed light into herbage mass may also be reduced. In swards at ceiling yields, where crop growth rates are zero, grazing may restore accumulation of herbage mass. This situation may occur in rotationally-grazed pastures with long regrowth periods and in pastures under summer and fall stockpile managements.

Reductions in the amount of energy absorbed by the sward due to grazing reduce the transpiration component of evapotranspiration (latent energy flux) and increase the sensible heat and soil heat fluxes, modifying the thermal environment of the soil, sward and grazing animal.

TILLER DYNAMICS

The responses of vegetative cool-season grasses to grazing and their recovery during rest periods is a function of populations and size of tillers (Simon and Lemaire, 1987). Grasses that produce and persist under grazing have the ability to adapt in terms of both size and population. Tillers of ryegrass and fescue can exist under close grazing or mowing as in turf yet can respond to long recovery phases and support high herbage mass. Grasses such as Kentucky bluegrass (*Poa pratensis* L.) lack such adaptability and produce lower yields.

TILLER MORPHOLOGY

Phytomer structure of cool-season grasses has been reduced during evolution in a similar manner to the reduction of floral parts. True

leaf lamina are absent in vegetative tillers and their functions have been taken over by petioles which have evolved into blades and sheaths (Langer, 1979). Fully developed leaf blades are dispersed in the canopy to facilitate photosynthesis while their sheaths are arranged concentrically, with the oldest on the outside. This structure supports the leaf display in place of a true stem (which does not develop). The concentrically-arranged leaf sheaths also shelter the growing point, tiller and leaf primordia and expanding young leaves. This sheath structure is called a pseudostem since it serves many stem functions. Many of the responses of grass swards under grazing are a consequence of its petiole morphology. The extinction coefficient, high optimun leaf area indices, capacity to accumulate high herbage masses and, perhaps, inferior quality (compared with legumes) are a few examples.

TILLER MORPHOLOGY AND THE GRAZING HORIZON

Pseudostems are likely to be of more significance in grazing of species that have the ability to form large tillers such as tall fescue (Festuca arundinacea Schreb.) and ryegrass (Lolium spp.) for they may determine the lower level of the grazing horizon (Barthram, 1980), the unavailable herbage mass, the level of utilization, height-intake functions and the rate of recovery. The pseudostem stumps remaining after close grazing protect the next series of expanding leaves that form the new canopy. In tall fescue the height of the pseudostem is about 8cm in summer pastures and after grazing by cattle, some blade tissue (1-2cm in length) remains and probably contributes to regrowth.

Unless grazing at low allowances or at low levels of availability cattle will seldom eat grass tillers below the plane represented by the tops of the pseudostems. The pseudostem represents a physical barrier to the limited ingestive mechanics of grazing cattle. Sheep, however, graze white clover (Trifolium repens L.) between rejected grass pseudostems (L'Huillier et al., 1986).

The readily-grazed horizon of cool-season vegetative grasses is at a variable height above the soil surface. Tiller populations fluctuate through out the year in response to variable rates of production and mortality (Langer, 1979), consequently, the average age and size of tillers is continuously changing. Since width and length of blade and sheath of unstressed tillers increase progressively with age the height of pseudostem the grazing horizon may be elevated during the periods of growth when not grazed. The pseudostem height is also modified in summer tillers since they are seldom vertical. This feature and its effect on leaf angle, increases extinction coefficient and has been associated with summer slump of growth of cool-season grasses.

REGULATION OF TILLER PRODUCTION

Production and growth of tillers during the recovery phase gradually slow as herbage accumulates. Tillering in grazed stands responds to favorable nutrition, water supplies, temperature and energy often through mechanisms based on the availability of carbohydrate. Recently Argentina researchers have demonstrated the importance of phytochrome in regulating tillering (Casals et al., 1987). In sparse swards phytochrome, located near tiller bases, senses high proportions of red light relative to far-red light and stimulates the growth and development of tiller primordia located in leaf axils. In dense canopies decreases in red relative to infra-red wavelengths are detected by phytochrome which then stops the initiation of new tillers. Phytochrome is also involved in the etiolation response observed in the blade and sheath of grasses grown under shade. As a consequence of etiolation pseudostem height may also increase.

REGULATION OF SIZE AND POPULATIONS OF TILLERS

When the tillering ceases in a sward recovering from grazing, possibly because of the phytochrome response, it enters another critical phase of growth and development. The increasing size of tillers results in intensifying competition between tillers, primarily for light energy. The sward enters a period of self-thinning when weaker tillers die. In self-thinning populations the -3/2 thinning law is in force (Kays and Harper, 1974):

$$w = cp^{-3/2}$$

where w = mean weight of individual tillers
c = maximum weight of tiller
p = tiller population

This law is of significance in recovering swards since it predicts that tillers must either die if their weight (or area) increases or become smaller if they all survive. In practice both fates befall tillers for weaker tillers die and, in survivors, accelerated leaf senesence and leaf death reduces tiller size. When these events occur in recovering swards, quality declines and intake and productivity of livestock suffers.

ADAPTABILITY

Co-evolution of grassland species and grazing herbivores has been responsible for many of the features of both present day grassland species and domestic livestock (Stebbins, 1981). Characteristics of grasses, such as the protected growing point, are widely recognised adaptations to selection pressures during evolution. Some grasses have options that are expressed during stresses such as those that occur during grazing. Axillary buds give vegetative grasses a major advantage during grazing. Options of the axillary bud include,

not growing, growing as a tiller, or growing as a rhizome or as a stolon. Grasses that survive under intensive grazing may have all these options open.

Perennial ryegrass is an example of one of the modern grasses best suited to grazing under lax or intensive, rotational or continuous grazing. Stolons or rhizomes are seldom mentioned in descriptions of perennial ryegrass, but Korte and Harris (1987) found 2420 stolons/m^2 and 6985 tillers/m^2 in grazed pastures in summer with 79% of tillers attached to stolons. Stolons formed in grazed swards after tiller bases were covered by earthworm casting or were pushed into soil by animal treading. Korte and Harris (1987) found 40, 450, and 2000 stolons/m^2 in spring, during culm elongation, and during summer, respectively, in another study. Rhizomes are also found in tall fescue (Porter, 1958) and are common under intensive turf management (A.J. Powell, pers. comm.).

CONCLUSIONS

Grasses suited to intensive rotational grazing may have considerable versatility in expression of morphological features. Grasses adapted to grazing have the capacity to produce tillers of a wide range in sizes, they have the ability to increase or decrease tiller populations according to management and environmental stresses. Adaptability of grasses to grazing may also depend on the versatility of axillary buds to produce tillers, rhizomes or stolons under grazing. Several of the responses of swards to grazing are related to changes in the light environment. The grass sward under grazing is a complex and dynamic ecosystem that is, and will continue to be, difficult to describe and quantify in terms of physiology and ecology.

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ECOLOGY AND PHYSIOLOGY OF WARM SEASON FORAGES IN INTENSIVE ROTATIONAL GRAZING SYSTEMS

F. M. Rouquette, Jr.[1]

As early as 1598, Archibald Napier of Scotland suggested a system of rotational grazing along with the use of common salt as a fertilizer. In addition, he received a patent from James VI for this idea and was to be paid 10 shillings per acre for its use. In 1755, James Anderson advised farmers to divide pasture land into 15 to 20 divisions and to allow animals to graze one division at a time. By 1788, Marshall suggested that farmers should divide their pastures into three parts with fattening cattle or dairy cows given the first bite of each division and then to be followed by replacement or dry stock. Each division would then be rested. And, in 1800, John Thompson recommended rotational grazing because it would increase grass yield. He concluded that too heavy grazing pressures caused reduced forage yields and caused animals to consume too little forage. Although the professional research community has given renewed attention to rotational systems of grazing, many of the concepts and philosophy surrounding this method of grazing are 200-400 years old. One of the common denominators to the historically used rotational grazing techniques is that most of these systems were used with temperate forages such as species of Lolium, Trifolium, etc. Thus, some of the factors which have encouraged the use of rotational grazing of the warm-season forages include historical observations, clipped plot data, grazing data from temperate species, and grazing data from arid or semi-arid environments. There is a general lack of data which investigates the ecology and physiology of warm season grasses used in intensive rotational grazing systems in the humid southeastern U.S.

CLIPPED PLOT STUDIES

Warm season perennial grasses of the southeastern U.S., and particularly the bermudagrasses, have been typically exposed to clipping studies which sought to determine the influence of defoliation frequency and severity on forage dry matter, and nutritive value attributes. Holt and Lancaster (1968) reported data from a 5-year study which indicated that dry matter yields of Coastal bermudagrass were greater with a short stubble height (2"), infrequent harvest (14-16" stubble) and nitrogen fertilization (240 lbs/ac). The height of cutting was less important in bermudagrass production than either frequency of defoliation or level of nitrogen fertilization. It was concluded that Coastal bermudagrass will tolerate a wide range of height and frequency of defoliation regimens. Clapp et al. (1965) obtained maximum yields from Coastal bermudagrass by harvesting at a .75 inch stubble each time a 2-inch height was obtained. This treatment included 23 harvest dates during the season and produced the highest initial yield each spring which indicated an adequate root reserve or tiller development. Prine and Burton (1956) and Burton et al. (1963) reported increases in bermudagrass yield with less frequent cutting with maximum production occurring at the 6-week harvest frequency. Quality, however, declined with each delay in harvest. Holt and Conrad (1984) evaluated several bermudagrass selections at harvest frequencies at 3, 6, and 9 weeks during a 3-year period. Dry matter production ranged from about 5 tons/acre for Callie to nearly 7.5 tons/acre for Coastal. They also reported no additional increases in yield after a 6-week interval.

Rouquette and Florence (1981) evaluated the effect of 1, 2, and 4-week harvest intervals on dry matter production, vigor, and density of several bermudagrasses for a 3-year period. Bermudagrass yield at the 4-week interval was nearly twice that of yields from the 1 and 2 week harvest intervals. Although dry matter production, vigor and density rating varied among bermudagrasses, harvest frequency did not affect vigor within a bermudagrass selection. Density ratings were generally higher on the more frequently harvested plots. Grass vigor and its ability to survive under grazing conditions is related to type (bunchgrass vs sodgrass) and its resistance to grazing under a given set of environmental conditions. Briske (1986) modified the approach taken by Levitt (1980) and concluded that grazing resistance was dependent upon both an avoidance and tolerance mechanism. In this context, a tolerance mechanism encouraged regrowth following defoliation and was dependent upon both morphological and physiological parameters. An avoidance mechanism, on the other hand, essentially reduced the probability of defoliation and was dependent upon morphological parameters as well as biochemical compounds.

Leaf to stem ratios of bermudagrass varies with the season, but generally, leaf production peaks at 20-24 days in early summer and at 28-32 days in late summer (Peterson, 1988). Stem production continues to accelerate with age which drastically alters the leaf:stem ratio as well as nutritive value. Most of these clipping studies have attempted to critically evaluate defoliation regimens as they may impact hay production and related management techniques. Clipping studies have always provided certain baseline data from which grazing studies have been initiated. However, many have made direct translations that clipped plot data simulates grazing data. Unfortunately, clipped plot data simulates mowing or haying conditions much more proportionally than grazing conditions. However, many of the previously documented rotational grazing schemes included graze-rest periods on multiples of 7-day increments.

GRAZING STUDIES

Most of the ecological and plant physiological measurements of rotationally grazed pastures have been conducted using temperate grasses and/or

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clovers. A few examples of similar research with tropical or warm-season grasses will be used for illustrative purposes but do not represent a complete literature review. Bransby (1983) used Coastcross II bermudagrass in a 4-year study to evaluate the influence of variable stocking rate under both continuous and rotationally grazed systems. The rotational scheme at each level of forage availability consisted of 6 paddocks with residence time in each paddock of about one week and recovery time of about 5 weeks. As stocking rate was increased, the rotational grazing method had an increasing advantage over continuous grazing as measured by available forage. In other words, at the same stocking rate, there was more forage available for consumption in the rotationally grazed system as compared to the continuously grazed pasture. At equivalent levels of forage availability, average daily gain (ADG) was greater for animals on the continuously grazed areas compared to the rotationally grazed paddocks. It was concluded that the lower ADG from animals assigned to the rotational scheme results from forced consumption of 5-week old forage which was low in quality, and a possible behavioral problem associated with paddock size and movement schedules.

Conrad (1982) grazed both Callie and Coastal bermudagrass rotationally and continuously at each of four set stocking rates. A 7-day graze, 21-day rest scheme was used in the rotational paddocks. Although steers grazing Callie had a 12% advantage in ADG, there were no differences between grazing method within bermudagrass hybrid as measured by ADG over the 2-year study. The greatest difference between hybrids occurred at the lightest stocking rates (2.7 and 3.2 hd/ac) where animal selectivity was optimum. In an extension of this study, Kanyama-Phiri and Conrad (1986) evaluated the influence of grazing method (continuous vs rotational) and stocking rate on grazing behavior, animal performance, and sward response. Forage-on-offer, bite rate, and bite size decreased from day 1 to day 7 of the residence time in each paddock, but remained relatively constant across all stocking rate pastures. Percent leaf of the sward under continuous grazing was nearly identical across all four stocking rates at 51% leaf. Under the rotationally grazed scheme, percent leaf in the sward on day 1, 4, and 7 of the residence period was 72, 52, and 50%, respectively, across all stocking rates. The mean percent leaf during the 7-day period was 57, 54, 59, and 62%, respectively, for high, moderately high, moderately low, and low stocking rates. Percent leaf of animal extrusa as measured esophageally was about 82% across all stocking rates on the continuously grazed pastures and about 86% on the rotationally grazed paddocks. Roth et al. (1985) used stocker cattle to graze Coastal bermudagrass to four levels of availability. Percent green leaf in the sward ranged from about 40% on the low stocked pastures (2500 lbs body weight per acre) to about 50% on the high stocked pastures (8000 lbs body weight per acre). However, percent leaf of the animals' diet was approximately 80% and was not affected by level of forage availability or stocking rate. In the Kanyama-Phiri study, percent leaf of animal extrusa was 94, 84, and 80% respectively, on days 1, 4, and 7 of the residence time. The benefits derived from the 94% leaf in the diet of the animals on day 1 was offset by the lack of forage availability on day 7. Thus, this data may suggest that if rotational grazing is to increase ADG and/or gain per acre over continuously grazed pastures, then either: (a) residence time may need to be dictated by forage availability rather than a set number of days, and/or; (b) more than one set of grazers may be necessary to avoid the complete utilization of mature bermudagrass forage which is high in percent stems and low in nutritive value. Further quantification of the bermudagrass sward by Kanyama-Phiri (1988) showed that both percent protein and in vitro digestible dry matter (IVDDM) were lower on the continuously grazed pastures as compared to those grazed rotationally. In each grazing system, the sward was partitioned into an upper, mid- and lower portion. The lower portion of the sward was 35-40% lower in protein and 16-18% lower in IVDDM as compared to the upper portion of the sward.

Under more arid conditions, Heitschmidt et al. (1987) used a 16-paddock rotational grazing scheme and a continuously grazed range area to evaluate the effects of grazing system on vegetation responses and cow-calf production. Residence time in each paddock ranged from 1 to 4 days with a rest period of 30 to 65 days. The total herbaceous standing crop was greater in the continuously grazed areas because of a greater amount of senesced forage, however, method of grazing did not affect herbage growth dynamics. Forage quality was generally higher in the rotationally grazed paddocks. It was concluded that stocking rate and not the method of grazing was responsible for differences that occurred among treatments. And, further, that the rotational grazing scheme influences carrying capacity (10-15% improvement) and overall range condition by enhancing grazing distribution rather than increasing forage production. Stuth et al. (1987) simulated a 16-paddock, one herd, short duration grazing scheme under four stocking rates to quantify various plant-animal interactions on a little bluestem-brownseed paspalum savanna. Stocking rate altered the composition of species grazed, affected the amount of live tissue that escaped grazing, and reduced the total amount of lamina during the succeeding grazing period. Increased stocking rates negatively affected the number of active meristems and associated root systems. Under a moderate rate of stocking, previous defoliation and number of live leaves influenced the grazing of a little bluestem tiller, and previous grazing history and amount of live lamina influenced the selection of a brownseed paspalum tiller. Selection of little bluestem was influenced by abundance and morphology of the plant with abundance becoming more important as stocking rate increased. Brownseed paspalum, on the other hand, was selected primarily

because of morphology, and selection was not greatly influenced by abundance or stocking rate. As stocking rates were increased, intake of protein was maintained by an increase in selection of dicots. Season of the year was the most important factor affecting grazing behavior.

SUMMARY

There is a definite void of basic physiological data from rotationally vs continuously grazed warm-season grasses. Most of the grazing studies have reported definite quality advantages and some dry matter production advantages for rotationally grazed warm-season grasses. From the standpoint of animal performance, however, little if any advantages in ADG have been reported. Quality of the lower portion of the warm-season grass sward is usually dramatically lower than the quality of the upper portion of the sward. This same trend is not the case with perennial ryegrass or other temperate grasses. Thus, the forced consumption of the low quality stems in the lower strata of the warm-season grass sward has probably served to offset the beneficial effects of a rest-graze scheme. Certainly, the research efforts with perennial ryegrass (Parsons et al., 1988) serve to illustrate the need for similar research with tropical forages. In the most elementary scenario, as long as stocking rate allows for selective grazing, all grazing could be classified as rotational grazing. However, under most commonly accepted definitions, rotational grazing requires several paddocks (more than one) with some graze-rest period. Unfortunately, the decision to graze warm-season grasses rotationally is usually based on testamonial-type information rather than scientific fact. It is generally understood that a multi-paddock divided farm has more flexibility than a single paddock. And, this is especially true when optimum forage utilization is to be attained either from grazing and/or mechanical harvesting. Certainly the dramatic quality differences within the sward of the warm-season grass, and the stubble height or forage availability of the residence paddock are primary factors to consider before entering into the economic and time demands of a rotational grazing scheme. The primary objective of the grazier of warm-season grasses is to make optimum biological and economic utilization of forage that is produced, and at the same time, to prevent the deterioration of the soil-plant resource.

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CARBOFURAN FOR FORAGE ESTABLISHMENT: AN UPDATE

D. D. Wolf[1]

Seldom can the "bottom line" be stated in the beginning. This situation may be appropriate as far as possibilities for future approval of carbofuran that can be used for establishment of forages other than alfalfa. The new label for carbofuran includes the entire United States as far as alfalfa establishment is concerned. Either broadcast spray or granules can be used with the restriction that the material is incorporated. No-till plantings where granular carbofuran is applied in the row with the seed has been interpreted to be adequate incorporation. Regardless of the benefits that can be proven by research for other forage there will probably never be approval for additional usage. Everyone will agree that the hazards with new crops are no greater than with other crops with current approval; however, due to the extremely high cost to do the investigative research and the low potential return, companies are not willing to invest in procedures for expanding registration. State and federal government agencies prohibit written recommendations that are not specifically stated as approved in registration.

Some possibilities for approval of carbofuran use on new crops may exist. Since warm-season grasses will not be used for grazing for one year, a non-food crop designation could be used. This may free us of establishment of tolerances and need for toxicology information. If considered as a non-food crop then a special needs (24C) or an experimental use (Sec. 18) registration may be possible. Also there is a provision for a "third-party" label. This means that a group such as a state Forage and Grassland Council could request 24C registration. At present there is a serious effort to find some way to gain legal registration for carbofuran use in forage seedings where beneficial. Such food crops as peanuts, sweet corn, and potatoes have registered usage even though they are consumed by humans in the year of planting yet no possibility exists for a crop to be consumed by livestock in the year after planting.

The mode of action of carbofuran where beneficial to initial growth and subsequent productivity of the plant has not been confirmed. Often some insects both soil borne and above ground can be reduced by the use at planting, however, when other insecticides are used to control the insects there is an unexplained additional benefit from carbofuran. Often this benefit appears to be in the nature of a plant growth stimulus that can occur early in germination, as is seen by increased seedling population, and can carry into yield productivity of the mature plant.

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ALFALFA.

Benefits from carbofuran in alfalfa establishment are not consistent. Recommendations vary among states. Some states make no recommendation for usage but indicate that there can be some benefits if used. Other states make recommendations for usage in both conventional and no-till alfalfa plantings. Benefits are most consistent when no-till plantings are made into a field where the previous cover has been some type of perennial vegetation as compared with a previous crop of small grain or millet. Dramatic benefits from carbofuran can occur where infestation of seed corn maggot exists. There is some indication that benefits have been most prevalent where alfalfa is planted into cool moist soil. These data indicated that carbofuran may be acting as a fungicide in the control of diseases in the seedling stage.

COOL-SEASON GRASSES.

Establishment of endophyte-free tall fescue has sometimes been less successful with weaker stands occurring as compared with endophyte-infected tall fescue. A large planting made in southeast Virginia had adequate stands of endophyte infected tall fescue, however, in a very similar planting of the experiment endophyte-free fescue was a failure. Where endophyte-free tall fescue failed there were places where the planting equipment passed through cow paths. The clear areas without vegetation had adequate stands which lead to the suspicion that either disease or insects was contributing to the failure. A benefit of carbofuran for tall fescue plant population, plant height, and stand rating was observed in unpublished data at the University of Maryland (Table 1). The level of endophyte was not established but probably the seed was infected. Unpublished data from the University of North Carolina indicate an advantage in seedling population resulting from the use of carbofuran at each of three

planting dates (Table 2). The influence on subsequent productivity is not available from these experiments but as with many plantings where early stimulation of seedling growth has occurred, compensatory plant development soon masks any early advantage in the seedling stages of development. Recommendation can not be made due to the label restriction for the use of carboufran.

Table 1. Plant population, plant height, and stand of tall fescue and switchgrass as influenced by carbofuran. Unpublished data from Morris Decker Maryland, 1981. Data taken 2 months after seeding, average of 3 planting dates.

Species	Carbofuran	Pop.	Height	Stand
Switchgrass	No	9.2	11.4	1.3
	Yes	10.2	14.4	2.6
Tall fescue	No	14.4	7.6	1.2
	Yes	17.8	9.4	2.2

Statistics not available.

[1]Population = no./ft^2, height = inches, Stand = rating with 1 being low and 5 high.

Table 2. Plant population of Forager tall fescue planted at 3 dates as influenced by carbofuran drilled in the row with the seed at 1.7 kg ha^{-1}. (Unpublished data from Doug Chamblee, University of North Carolina).

Planting date	Carbofuran No	Carbofuran Yes	Dif.
	- No. ft^{-2} -		
1 Sept.	3.0	7.0	4.0
1 Oct.	6.0	14.5	8.5
21 Oct.	12.0	14.0	2.0
Avg	7.0	11.8	4.8

WEEDS.

Phenomenal advantages of carbofuran in the growth and development of some weeds such as crabgrass, fall panicgrass, Johnsongrass, and spiney pigweed have been observed. These responses have not been documented in the literature but observed by Extension Specialist and research workers under field situations. The stimulus of weeds could lead to serious problems if competition is greater for the planted crop where carbofuran is applied than without application. Furthermore, established stands where carbofuran is used as an insecticide could be counter productive in stimulating the competition of existing weeds. There is some evidence to indicate that warm-season C-4 plants are the most likely to be stimulated by the presence of carbofuran.

TALL-GROWING PERENNIAL WARM-SEASON GRASSES.

The dramatic benefit of carbofuran when used with warm-season grasses such as switchgrass and Caucasian bluestem has been observed and documented by many research and Extension workers (Table 2,3). The use of either broadcast spray or granular formulation with the seed is effective in increasing seedling population and vigor of the seedlings. Lorsban insecticide did not increase plant population and had only moderate influence on vigor. Therefore, increased population from carbofuran could be interpreted to be due to non-insecticidal benefits while vigor of the seedling could be considered as about 66% of the increase that could be attributed to carbofuran (Table 3). Some extreme weed competition has occurred from warm-season annual grasses as mentioned above which may have been in part due to the stimulus of carboufran.

Table 3. Switchgrass (Pathfinder seedling population and vigor as influenced by Furadan and Lorsban placed in row as granules at 0,1, and 2 lb./acre and Furadan broadcast at 2 lb./acre. Data are averages of no-till plantings on 2 and 15 May 1987 using 4.2 lb. PLS/acre.

Insecticide	Placement	Rate (lb./acre) 0	1	2
		Pop. (No./sq. ft.)		
Furadan	In row	17.7b*	25.8a	25.0a
	Brdcast	17.7b	-	26.2a
Lorsban	In row	17.7b	17.8b	17.2b
		Vigor rating		
Furadan	In row	2.7c	9.3a	9.2a
	Brdcast	2.7c	-	9.0a
Lorsban	In row	2.7c	4.8b	5.4b

*Means followed by similar letters do not differ significantly at the 0.05 level.

Cave-in-rock switchgrass was no-till planted on 22 April, 15 May, and 15 June in a 1987 study. Seedling population was more than doubled with the application of Furadan as compared with the check at all seeding dates. Seedling weights from carbofuran treated plots were about 3 times greater than seedlings without carbofuran (Table 4).

Table 4. Switchgrass seedling population and weight (at 5th leaf stage) as influenced by carobufran and planting date in 1987.

Planting dates	Carbofuran(lb/a) 0	1
	pop. (no./ft^2)	
22 April	5.0	12.5
15 May	6.8	13.3
15 June	6.6	12.6
Avg.	6.1	12.8
	mg/seedling	
22 April	24	86
15 May	19	56
15 June	66	166

Excerpts from a thesis recently completed by Jim McKenna at Virginia Polytechnic Institute and State University will be presented in order to document the responses of switchgrass and Caucasian bluestem to carbofuran at seeding.

Plantings of two tall-growing, perennial, warm-season grasses were made in Blacksburg, VA on a Groseclose loam soil (clayey, mixed, mesic Typic Hapludult). Establishment of switchgrass and Caucasian bluestem using no-till procedures was evaluated with treatments of carbofuran. Seedling growth rate and leaf appearance rate were recorded prior to the sixth-leaf stage of development. Seedling weights, populations, and heights were measured at the sixth-leaf stage of development. Leaf elongation rates were measured for leaves 7, 8, and 9. Yields of forage and percentage perennial warm-season grass in the harvested herbage were determined in the year of planting and the year after planting. Our data indicate that 1.1 kg carbofuran/ha, placed in the row with the seed at the time of no-till planting enabled seedlings to develop faster, elongate more rapidly, and provide more and heavier seedlings than without carbofuran. Carbofuran at the time of planting increased yields in with both species (Table 5). Carbofuran at 1.1 kg/ha was considered the best recommendation for establishment of switchgrass and Caucasian bluestem.

Table 5. Influence of carbofuran applied in the row with the seed of switchgrass and Caucasian bluestem on seedling leaf elongation rate (LER), seedling population, seeding weight, and herbage yield from Ph.D. thesis by Jim McKenna, VPI & SU, Blacksburg, VA.

Species[1]	Carbo-furan	Seedling[2] LER	Pop.	Wt.	Yield first cut
Switch-grass	0	26	201	132	0.73
	1.1	43	361	338	1.56
	Dif.	**	**	**	**
C. Blue-stem	0	51	207	50	0.93
	1.1	70	612	74	2.39
	Dif.	**	**	**	**

[1]Switchgrass data are averages of 1985 and 1986 plantings. Caucasian bluestem data are from a 1985 planting.

2LER = mm/d, Pop. = No./m^2, wt = mg/pl, yield = Mg/ha.

**Indicates a significant difference between carbofuran rates at the 0.01 level or less.

FORAGE UTILIZATION INFORMATION EXCHANGE GROUP

USE OF NIRS TO PREDICT BOTANICAL COMPOSITION OF FORAGE MIXTURES

N. S. Hill, J. A. Stuedemann, and G. O. Ware[1/]

INTRODUCTION

By now all of us should be aware of the benefits of rapid and accurate analysis of feedstuffs using near infrared reflectance spectroscopy (NIRS). For those of you who have not been associated with NIRS analysis and wish to become more familiar with the technology, the USDA-ARS Agricultural Handbook No. 643, "Near Infrared Reflectance Spectroscopy (NIRS): Analysis of Forage Quality", is an excellent beginning manual to review. The first printing is no longer available but it is being revised and the second printing should be available soon.

The majority of the NIRS research analyzing forages for feed have been with conserved forages for feed formulation (Martin and Linn, 1985; Norris et al., 1976; Shenk et al., 1979). The homogeneous and static nature of conserved forages made the feedbunk an attractive arena in which animal nutrition and forage quality scientists could begin evaluating NIRS technology and its applicability to the plant-animal interface. For example, monthly testing of forage inventories, and the resulting feed formulations, have increased protein and fat content from four Minnesota dairy farms without adversely affecting milk production. In that same study, farmers realized about $2,000 in savings on feed cost by reduced protein supplementation (Walter et al., 1987).

THE PASTURE-ANIMAL INTERFACE

Matching animal needs with forage quality in the pasture environment is a more crude estimation because scientists don't have the luxury of working with forages that are homogeneously mixed (as in silages) or whose quality changes little with time. Brown et al. (1987) described the pasture plant-animal interface as being dynamic, whose changes are a function of animal defoliation of the pasture canopy, and the changing pasture canopy effects on ingestive behavior of the animal. The changes which occur in the pasture during defoliation are most evident in grass-legume mixtures of rotational grazing systems. Animals that rotationally grazed stargrass-aeschynomene pastures preferentially grazed leaves over stems and aeschynomene over stargrass (Brown et al., 1987). In a similar experiment where animals rotationally grazed alfalfa-orchardgrass pastures, it was found that pasture nutrition was high at the onset of grazing but considerably lower at the end of the grazing cycle (Blaser et al., 1986, 1977). The relationships between selectivity, digestibility, intake, and grazing pressure from rotationally grazed pastures are summarized in Table 1. From this it becomes evident that under low grazing pressures, when selectivity, intake, and digestibility of the grazed forage is high, animal performance is expected to be high. Conversely, when grazing pressure is high, selectivity, intake, and digestibility are low and animal performance is expected to be lower. In practice, there is a lag in animal performance when animals are moved from low quality pasture to high quality pasture in a rotational grazing system. This was demonstrated with milk cows which rotationally grazed pasture cells for eight days. After rotating to fresh pasture, a 2-3 day lag occurred until milk production peaked after which production steadily declined (Blazer et al., 1986). Therefore, performance of the pasture animal is a function of available herbage, the ability of the animal to obtain a quality diet by selecting more nutritious plant species and plant components of the species in the pasture, and the residual effect of lower quality digesta in the rumen after changing pastures. The problem facing pasture and animal scientists is how to minimize nutritional fluctuations through pasture and animal management and match available nutrition of the pasture with nutritional demands by the amimal without sacrificing complete utilization of the pasture herbage. Experiments designed to study the plant-animal interface in the pasture require extensive sampling, chemical, and botanical analysis to accurately determine the sequence of events which result in animal performance. Therefore, analysis by NIRS is an attractive alternative laboratory analysis because of the expeditious manner in which it analyzes large volumes of samples.

NIRS CONCEPTS

Near infrared analysis of samples is based upon absorption, re-radiation, and reflection of near infrared light by the functional groups of molecules which are components of chemical constituents in the forage (Norris, 1985). These may be peptide, carboxyl, acetyl, hydroxyl, aldehyde, or ketone groups, to name a few. Therefore, NIRS methodology is best suited for <u>chemical</u> analysis of pasture, esophageal, and fecal samples. However, a series of epxeriments reported in the literature suggests NIRS can also be used to estimate components of herbage and esophageal samples which do not have specific and unique chemical constituents.

Coleman et al. (1985) were the first to test the hypothesis that species composition of hay could be predicted using NIRS methodology. Using artificial mixtures of cool and warm season grass species and a dicot weed, they demonstrated that NIRS could accurately and precisely predict components of the mixtures.

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In a second experiment where samples of pure hay were taken from feed troughs to create artificial mixtures for NIRS calibration and prediction, precision (and in one species accuracy) was reduced. This suggests that extreme care must be taken to properly sample the units to be estimated by NIRS.

A second experiment which demonstrated the usefulness of NIRS analysis in predicting botanical composition was that of Petersen et al. (1987). They found that pasture samples from 0.1 m^2 quadrats harvested in May and August could be analyzed for tall fescue and white clover when hand separations of pasture samples were used to calibrate the NIRS instrument. Their study suggests that proper selection of a proportion of the samples is necessary to calibrate NIRS for accurate prediction of botanical composition in pasture samples.

Thirdly, it has been demonstrated that leaf components in alfalfa samples can be accurately and precisely predicted by NIRS (Hill et al., 1987). When saliva was added to the samples in varying concentratons, there was little effect on the ability of a NIRS calibration to predict leaf in samples without added saliva and vice versa. In fact, the same math treatments of the spectral data were selected for calibration equations developed for samples with or without added saliva, and of a possible eight wavelength matches between the two equations, seven were identical (Table 2). This suggests that not only can NIRS be used to predict botanical composition and plant components in pasture samples, but that the same measurements can be made in esophageal samples from a calibration equation generated from pasture samples.

ERRORS ASSOCIATED WITH NIRS ANALYSIS

As with any laboratory analytical procedure, NIRS has error associated with its analysis. When predicting chemical or botanical constituents of the sample, two sources of error can be measured. The first, the bias, is an estimation of how accurately NIRS is predicting the laboratory value of the sample. Therefore, it can be used as an evaluation of whether NIRS systematically over- or under-predicts the laboratory value of the samples. The second, the standard error of prediction (SEP) is an estimation of the precision with which NIRS predicts the laboratory value of the sample. The SEP, although called a "standard error", is the square root of the mean square error, or standard deviation, between the NIRS analysis and laboratory values (Martin and Linn, 1985). Therefore, the SEP can be used to calculate a boundary on the error of the estimation using Eq. [1] (Mendenhall, 1987).

$$B = \frac{t\sigma}{\sqrt{n}} \qquad \text{Eq. [1]}$$

where: t = t value based upon NIRS <u>sample</u> size used to determine the <u>SEP</u>
σ = SEP
n = <u>pasture sample</u> size
B = boundary

For example, if NIRS is calibrated for a pasture species component using 51 samples, and has an SEP of 4.50%, the boundary of a single observation (n = 1) is:

$$\frac{2.008(4.50\%)}{1} = 9.04\% \qquad \text{Eq. [2]}$$

Having a boundary of 9.04% may not be acceptable, particularly when it may be as high as the mean. So the logical question is, "How does error associated with NIRS analysis affect the estimation of my pasture components?". The answer is that the boundary of the NIRS analysis is a funcation of the number of samples, or repeated observations, you obtain to estimate your pasture. Using Eq. [1] one can calculate the boundary of the NIRS mean value. To demonstrate the concept, consider the following experiment.

In 1987, a study was initiated to determine diet selection, digestibility, and intake of steers rotationally grazing alfalfa, tall fescue, and two alfalfa-tall fescue mixtures. Stratified pasture samples were obtained to provide a three dimensional analysis of botanical composition and the plant components (alfalfa leaf, stem and tall fescue leaf). Because of the labor required for separation and chemical analysis, NIRS methodology was chosen to analyze the samples.

Each day of the experiment 8-0.5m^2 samples were clipped from each pasture and a portion (about 20% of the total sample number) were hand separated into alfalfa leaf, alfalfa stem, and tall fescue fractions. The fractions were weighed to obtain the percentage of each, then remixed, ground through a cyclone-type mill, and scanned by NIRS. Two-thirds of the hand separated samples were used to calibrate NIRS and one-third used to validate the calibration. The NIRS validation statistics are provided in Table 3. By knowing the number of samples in the validation set and the SEP for each component, the boundary of the NIRS analysis can be determined if one were to sample 1, 5, 8, or 10 samples per pasture using Eq. [1]. From the calculations (Table 3), it becomes evident that the boundary of the NIRS estimate is inversely related to the number of samples obtained to estimate the pasture.

Because biases of the NIRS predictions were small, the mean of the NIRS predictions would be expected to lie within the NIRS boundary of the mean of the hand separated values for the 1, 5, 8 or 10 pasture samples. Comparisons of NIRS predicted and laboratory means for the

pasture components among samples were similar (Table 4). In addition, standard deviations of the pasture samples for both NIRS and laboratory values were similar suggesting the variability between pasture samples had a greater effect on variability among NIRS predictions than error associated with the spectral analysis.

CONCLUSIONS

NIRS can be used to predict chemical or botanical composition, and plant components of pasture and esophageal samples. Because the accuracy and precision of the prediction are dependent upon how the calibration subset is selected from the entire sample population, NIRS will not totally replace laboratory analysis of the samples. Therefore, NIRS is best suited for experiments where large sample numbers are generated.

The accuracy of the prediction is never guaranteed to be below the boundary for NIRS predicted means of the pasture samples. It is possible that the error estimate will exceed the bound, but depending upon the probability designated when determining the "t" statistic, it is unlikely.

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Table 1. The effect of grazing pressure on animal selectivity and dietary digestibility and intake. (From Blazer et al., 1977).

	Grazing pressure		
Item	L	M	H
Selectivity	H	M	L
Digestibility	H	M	L
Intake	H	M	L

L, M, H = Low, medium, high, respectively.

Table 2. Calibration statistics and wavelength selection by NIRS to predict percent leaf in alfalfa with saliva treatments.

Treatment	Calibration Statistics					
	DN	DC	SL1	SL2	R^2	SEC
No Saliva	1	20	20	2	0.97	4.69
Saliva	1	20	20	2	0.98	4.53
	Wavelengths Selected, nm					
No Saliva	2378,2258,2238,2218,1998,1758, 1718,1138,1118					
Saliva	2318,2258,2238,2218,1998,1758, 1718,1138					

Table 3. Boundaries of NIRS prediction means for pasture components when different numbers of samples (n) are used to estimate the pasture means.

Component	N	$\bar{X}$ NIRS	SEP	Bias	Boundary when n = 1	5	8	10
		- - - - - - - - -	- - -	- - - % Units	- - -	- - -	- - -	- - -
Fescue	25	37.0	3.4	-0.9	7.0	3.1	2.5	2.2
Alfalfa leaves	25	39.9	4.4	0.1	9.1	4.1	3.2	2.9
Alfalfa stems	25	24.1	5.5	-0.2	11.3	5.1	4.0	3.6

Numbers of samples in NIRS prediction file

$t_{.05,24} = 2.06$ for calculations.

Table 4. Hand separated (LAB) vs. NIRS predicted (NIRS) components of alfalfa/tall fescue pasture mixtures from stratified samples harvested on July 13, 1987.

		Strata (cm)							
		0-10		10-20		20-30		30-40	
Component	Method	$\bar{X}$	(SD)	$\bar{X}$	(SD)	$\bar{X}$	(SD)	$\bar{X}$	(SD)
		- - - - - - - - -	- - -	- - - % Units	- - -	- - -	- - -	- - -	- - -
Fescue	LAB	6.0	(1.8)	8.5	(6.4)	0.7	(1.1)	0.0	(0.0)
	NIRS	7.7	(4.4)	7.6	(4.7)	-0.1	(1.3)	3.8	(1.2)
Alf Leaf	LAB	34.8	(13.3)	54.9	(6.7)	77.7	(4.0)	81.3	(2.6)
	NIRS	34.1	(16.0)	56.1	(6.0)	78.3	(2.1)	80.2	(1.7)
Alf Stem	LAB	59.2	(11.9)	36.7	(4.2)	22.0	(3.9)	18.5	(2.4)
	NIRS	58.6	(13.8)	36.2	(3.4)	22.6	(4.6)	14.9	(0.2)
n †		4		4		7		3	

† SD = Standard deviation of the mean.

n = Number of subsamples analyzed.

FORAGE INTAKE AS INFLUENCED BY SWARD CHARACTERISTICS

T.D.A. Forbes[1]

INTRODUCTION

The efficient production of animal products from grazed forages relies largely on the producers ability to efficiently manage his resources. The most important resource the producer has is the forage that his animals graze, and his main objective should be to maximize forage intake by his animals. Efficient grazing management depends to a large extent on the producers understanding of the influence of sward composition and structure on forage intake. With such an understanding grazing management strategies can be devised that optimize productivity, reduce inputs into the system, and which reduce the element of risk.

FORAGE INTAKE

Conventionally, forage intake is determined over relatively short periods, usually seven days, and the results are then reported on a daily basis. For many purposes this may well be satisfactory. However, it may be more realistic to consider daily forage intake as the end result of a series of interrelated processes, beginning with the individual bite and including individual meals. The interpretation of the interrelationships between sward characteristics and animal behavior, both social and ingestive are the basis for plant-animal interface studies, and are essential to the understanding of how both swards and animals may be manipulated in order to achieve production objectives. The plant-animal interface, as defined by Moore and Sollenberger (1986), has been much discussed (Hodgson, 1982; Minson, 1983; Forbes et al. 1985; Moore and Sollenberger 1986), but has been studied in depth to a much lesser extent relative to its importance to animal production. Much of the work that has been done has been conducted in the United Kingdom (Jamieson and Hodgson, 1979a&b; Hodgson 1981; Forbes and Hodgson, 1985; Penning, 1986) or in Australia (Allden and Whittaker, 1970; Stobbs 1973a&b; Chacon and Stobbs, 1976; Chacon et al., 1978). Relatively little work has been done in the United States considering the range of forages and environments encountered (Forbes and Coleman, 1987 and unpublished; Moore et al. 1987; Stuth et al. 1987).

Intake in the grazing animal is a very much more complex process than metabolism barn studies would lead us to believe. Local climatic and inter-animal social factors can have large effects on intake, in addition to the effects of diet quality and quantity. Phillips (quoted by Butris and Phillips, 1987) found that DM intake of dairy cattle was related to the amount of rainfall by the expression y (kg DM/day) = 13.2 -0.48 mm rain day. The influence of both heat and cold stress on intake in grazing animals is well known (NRC 1981). However, the most important determinants of forage intake are sward based, and include mass or allowance, height, structure, botanical composition, as well as the quality aspects including digestibility, protein and fibre content. If it is accepted that animals are hedyphagic (McClymont, 1967) then it can be argued that most limits to forage intake are imposed by sward characteristics. Intake may be limited by three mechanisms: (1) Metabolic, (2) Distention, and (3) Behavioral (Moore and Sollenberger, 1986), acting independently or together. Metabolic control of intake is seldom encountered during grazing in productive animals and will not be considered further. Distention of the rumen or the intestinal tract (Waldo, 1986) is a likely form of intake control, particularly on abundant, poor quality forages such as are found in tropical and subtropical regions. In this case rates of digestion and passage are insufficient to allow the animal to take advantage of the time available to graze. The third control mechanism, that of ingestive behavior works through the influence of sward conditions on rate of intake and time spent grazing.

The Grazing Cycle.

Figure 1 shows a stylized and much simplified interpretation of the cycle of events from the start of one grazing period to the start of the next. Six phases and/or components are identified within each cycle. The accumulated quantity of forage eaten at each meal equals daily forage intake, and the number of cycles that can occur in any one day is influenced by both sward quantity and quality.

The grazing cycle starts with site selection. Grazing animals may have a great deal of choice or little or no choice as to where they begin grazing, depending on the type of management system they are in. Range animals will have the greatest choice while strip-grazed dairy cattle will have the least. Ignoring the extensive range system and the intensive dairy cow, most animals grazing sown swards have a limited range of choices. Should the animal graze a totally ungrazed patch that allows rapid satisfaction of its appetite but possibly at the expense of quality, or should it chose previously grazed patches which may be higher in quality but which provide small bite sizes and which may be depleted before the animal is full? Once the decision has been made, the animal starts grazing. At this point the eating drive is dominant, but that is not to say that the animal is particularly hungry. It only implies that other drives are currently

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set at lower levels. The intensity with which it grazes in terms of rate of intake is a function of both the eating drive and the sward structure. Rate of intake is the product of individual bite size and rate of biting, both of which are influenced by changes in sward structure.

The size of the individual bite is determined by the area encompassed by the mouth parts, including the tongue in cattle, the volume of the buccal cavity and the structure of the sward. Changes in the size of the mouth parts occur too slowly to influence the size of individual bites, except in the long term. However, the change from milk to adult teeth may have a considerable affect on potential bite size. Young animals appear to be more sensitive to changing sward conditions than adult animals (Hodgson and Jamieson, 1981).

Changes in sward structure are likely to be the greatest influence on reductions or increases in bite size. Sward structure may vary on both the large and the small scale, changing from patch to patch or from plant to plant. While the latter may result in bite size changing from bite to bite, it may be of little consequence relative to the much larger increases or reductions in bite size that may occur as animals move from one patch to the next. Due to the animals ability to compensate for reductions in short term bite size changes in sward structure over a period of days or weeks will have the greatest effect on forage intake. Individual bite size generally correlates better with sward height than mass over a range of sward types. It is likely, however, that individual bite size is more responsive to changes in density of leaf in the surface horizon or the leaf:stem ratio. Hodgson (1981) reported that bite size was more sensitive to variation in sward height than sward surface density. In contrast, T.H. Stobbs and co-workers, (Stobbs, 1973 a & b; Stobbs, 1975, Chacon and Stobbs, 1976, Chacon, Stobbs and Dale, 1978) found that on sub-tropical grass swards bite size was more sensitive to variations in sward surface density and leaf:stem ratio than sward height. Studies on warm-season grass swards in Oklahoma (Forbes and Coleman, 1987; and unpublished data) indicated that bite size was most sensitive to variations in leaf:stem ratio. On vegetative swards or swards without a tall diffuse flower-head horizon bite size appears to be positively related to sward mass, height and surface density (Hodgson, 1981; Forbes, 1988). However, with the appearance of an upper flower horizon bite size declines relative to sward height and surface density (Chacon and Stobbs, 1976; Chacon et al., 1978; Forbes, 1988). Bite size will also decline as swards are grazed down and the sward surface approaches the height of the psuedo-stem horizon (Barthram and Grant, 1984; Forbes and Hodgson, 1985).

Rate of biting is usually negatively related to increases in sward height (Allden and Whittaker, 1970; Hodgson, 1981) reflecting either the increased time required to masticate large bites or the difficulty in prehending preferred components within a low density canopy depending on the particular sward structure. As grazing continues bite size or rate of biting or both may decline, leading to a decline in rate of intake. On uniform swards the decline in rate of intake may be very abrupt occurring at the end of the grazing period. Under other circumstances it may be more gradually. Grazing stops when the eating drive is less than any one other drive, such as the need to drink, rest, seek shade or because the rumen is full. At this point the influence of sward structure ends and sward quality begins. Also at this point the animal will have eaten some proportion of its daily requirements for maintenance and production.

RUMINATION

After some indeterminate time interval rumination occurs. A detailed discussion of the mechanics of rumination will not be given here. The subject has been reviewed recently by Demment et al., (1987), Ellis et al., (1987), Martz and Belyea (1986), and Pond et al., (1987). Rumination serves to breakdown forage particles exposing internal structures to microbial attack (Pond et al., 1987), and the time spent ruminating increases with increases in forage maturity and fibre content. However, high quality forages appear to stimulate rumen motility and flow per contraction, perhaps explaining the high passage rates seen in such forages (Martz and Balyea, 1986). As emptying of rumen contents continues and the animal satisfies other drives, the eating drive once more becomes dominant, and the animal once more has to make a site selection decision. Sward conditions have, however, changed since the start of the previous grazing period and the animals choice of grazing site may reflect this. The rate of intake of the new grazing period will reflect the change in sward structure. The length of the grazing session will reflect the rapidity of the reduction in eating drive which, in part, is dependent on the amount of material that has passed from the rumen since the last grazing period. There is evidence, however, that sheep, at least, do not eat to maximum rumen fill at each meal (Thomson et al., 1985). These authors found that while legume forage resulted in lower levels of fill than grasses, maximum rumen fill was only found at the end of the afternoon grazing period. Forbes (unpublished) observed that cattle grazing winter wheat in the early spring had up to 14 distinct grazing periods in 24h compared with 4 periods per 24h when grazing warm-season grass in the summer months. This difference is most probably a consequence of differences in the quality of the forage influencing rate of passage, though the influence of cold stress on rumen emptying

may also be important (Kennedy, 1985).

In conclusion, sward characteristics impact on forage intake in two ways. Firstly, sward structure regulates the rate of intake. At low rates of intake, other drives, such as thirst, may override the eating drive before satiety has been reached. Secondly, sward quality determines the amount of time required for rumination, the rate of digestion and the supply of nutrients. Diets that contain high levels of indigestible fibre reduce the rate of passage of material from the rumen, and the rumen remains full for longer and is filled in a shorter period of time and subsequent grazing periods. Ultimately, the animal has to increase rumination time and the length of time between meals. Since, however, the time available for grazing is finite, the scope for increases in the number and duration of meals is limited and intake is depressed.

The producer, then, should aim to provide his animals with a sward that allows maximum rates of intake to be achieved. Tall, stemmy swards not only limit the rate of intake but also may be of such low quality that rumen fill limits the amount that can be eaten in any one grazing period. Carry-over effects then limit the number of grazing periods possible in any 24 hour period and consequently depress intake.

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THE GRAZING CYCLE

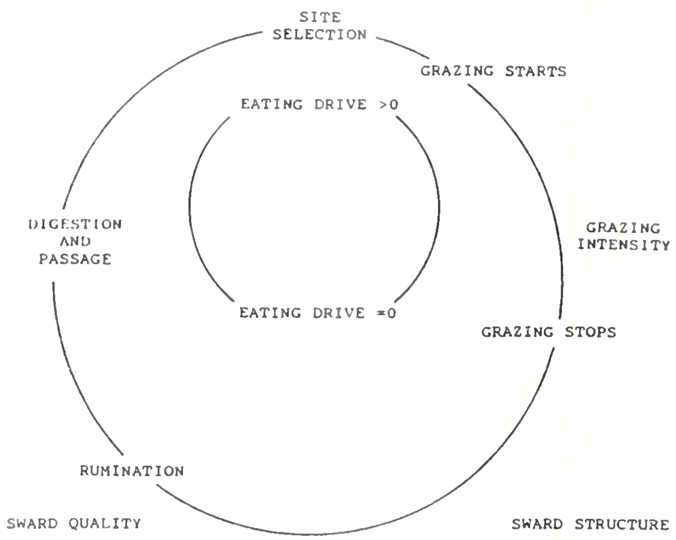

Figure 1.
The grazing cycle: major components in the cycle from the start of one grazing period to the start of the next grazing period.

BIOLOGICAL, PRACTICAL AND STATISTICAL CONSIDERATIONS ASSOCIATED WITH MEASURING FORAGE AVAILABILITY IN GRAZING TRIALS

David I. Bransby and G. Peter Clarke[1]

Introduction

Under grazing conditions, production per animal depends on the quantity of forage consumed (intake), but estimates of intake by grazing animals are often difficult to obtain. However, intake and production per animal are strongly influenced by forage availability which can be modified by adjusting the number of animals per unit area. In a sense, therefore, forage availability can be regarded as an index of intake by grazing animals. As such, it is an extremely important variable to measure in grazing trials. Our objective is to discuss some biological, practical and statistical considerations associated with measuring forage availability in grazing experiments.

BIOLOGICAL AND PRACTICAL CONSIDERATIONS

The purpose of forage availability measurements.

Forage availability measurements may be used in many ways to explain results from grazing studies. Only three situations are considered here. First, forage availability should be measured in single availability put-and-take trials in order to facilitate equalization of pasture conditions between treatments and replications, and within treatments and replications over time, by adjusting animal numbers. Early reports on put-and-take studies often did not include forage availability measurements (probably because forage availability was only visually rated) while more recent studies have usually quoted only an average or a range in availability for an entire experiment. Ideally, reports on put-and-take studies should include an analysis of forage availabiltiy data to indicate how successful the procedure was in maintaining a constant pasture condition across the experiment. Read and Camp (4) for example, showed that they were not successful in maintaining equal availability across treatments in a put-and-take trial which compared animal production from tall fescue (_Festuca arundinaceae_) with and without the fungal endophyte, _Acremonium coenophialum_. In such cases it may be appropriate to perform an analysis of covariance using forage availability as a covariate.
A second situation in which forage availability measurements are essential is where forage availability is varied experimentally. This facilitates the development of three important relationships (production per animal vs. stocking rate, production per animal vs. available forage, and available forage vs. stocking rate) and meaningful interpretation of results (1).

Finally by measuring forage availability before and after grazing a subdivision in a rotationally grazed treatment, an estimate of forage consumed by grazing animals can be made.

Expression of forage availability

Quantity of forage can be expressed in several ways (eg. kg forage per unit area, kg forage per unit weight of animals, kg forage per unit weight of animals per day or forage height). However, it is likely that forage availability affects intake and production of grazing animals through its effect on the ease of prehension of that forage. Consequently, the form in which forage availability is expressed should preferably reflect the ease of forage prehension by animals. In this regard, kg of forage per unit weight of animals may not be appropriate. For example, a one- and a five-ha field may each contain 2000 kg of available forage and 5 animals: the weight of forage per animal is the same but ease of prehension, intake and production per animal are likely to be different. Consequently, we recommend that forage availability be expressed either as kg of forage per unit area, or in terms of some height measurement when used to explain responses in animal production. Weight of forage per animal per day would likely have most application under rotational grazing. However, in order to estimate intake of forage by measuring availability before and after grazing a subdivision under rotational grazing, it is clearly necessary to express forage quantity as weight of forage per unit area.

Methods for measuring forage availability.

From a practical point of view, methods for measuring forage availability should

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preferably be (1) objective, (2) non-destructive, (3) quick and inexpensive, (4) repeatable and (5) simple in procedure and instrumentation. Generally, these methods can be divided into three categories: direct measurement by clipping quadrants or cutting mower strips, height measurements, and double sampling procedures in which some easy-to-measure forage attribute is related to forage yield. The main disadvantage of direct clipping is that it is labor-intensive and therefore expensive. It is also destructive. Height measurements may be made with a measuring stick, but these estimates are subjective and may be low in repeatability from one worker to another. Alternatively, height can be measured with measuring devices such as a disk meter or rising plate meter in which case repeatability should be high.

Many double sampling procedures for measuring forage availability have been used, including visual estimation, various kinds of electronic meters and disk or rising plate meters. Visual estimation is subjective and may be low in repeatability, while electronic meters require careful handling and can be expensive, fragile and sensitive to moisture in the soil. The disk meter (2,3) or rising plate meter method has provided good results in a wide range of conditions, but in certain situations (such as very tall pasture) it may be inappropriate. In general, however, it ranks well in terms of requirements 1 through 5 listed above.

Use of the disk meter involves two stages, as for any other double sampling procedure. The first stage, or calibration, requires the collection of a paired disk meter reading and weight of forage beneath the disk data set. The function of this calibration is simply to facilitate conversion of disk meter reading to kg of forage/ha. Therefore, these samples do not need to be randomly located. In fact, it may be better to deliberately select samples for calibration, in order to ensure that very low and very high values are included from the population to be sampled in the second stage. ie. the calibration should be representative. When developing the regression equation, the line should not be constrained to pass through the origin. Extrapolation of the line below the lowest value in the calibration may result in intersection of the horizontal axis. This is entirely reasonable, because even when no forage is present a reading above zero can be obtained from the disk meter due to uneven ground surface. On the other hand, extrapolation may result in intersection of the vertical axis. This may occur because (a) the true relationship between forage weight and disk height is not linear, yet it is being approximated by a straight line, and (b) all available forage above ground level is often not harvested.

Several factors are known to affect the calibration equation for the disk meter (2,3). These include different species, different seasons, reproductive vs. vegetative growth phases and grazed vs. ungrazed pasture. Separate calibrations should therefore be developed and tested for difference in each of these situations. Furthermore, the disk meter should not be used when forage is wet (from dew or rain) or under very droughty conditions (which cause plants to wilt) without specific calibrations for these conditions.

Sampling in the second stage (in which only disk meter readings are taken) should ideally be random. However, random location of disk meter readings in a paddock would be extremely time consuming. In most cases, disk meter readings taken in several transects across a paddock are satisfactory. Such transects should cut across any obvious variation in forage availability within a paddock.

STATISTICAL CONSIDERATIONS

Primarily we will look at the statistical efficiency of the two-stage sampling procedure based on the disc meter.

1. Description of the Method

Stage 1. - The calibration stage.

Site a total of n_1 (usually about 10) sample points across all paddocks in the experiment. This would normally be done systematically in an effort to ensure as wide a range of conditions as possible.

At each point:

(a) take a disc meter reading (h),

(b) mark out, as accurately as possible, the edges of the disc on the ground and cut off the forage within the delineated circle, dry the cut forage and record the weight (w),

(c) fit a linear regression equation to the data pooled from all the

paddocks, giving a regression equation of the form:

$$\hat{w} = a + b\,h \qquad \text{-----}\ [1]$$

where $\hat{w}$ is the predicted weight of cut forage from a point with disc meter height h.
Also conduct an auxilliary Analysis of Variance, where from the pooled data, the total sum of squares for weights w is subdivided into regression and deviations and we eventually calculate S^2, the deviations mean square.

At this stage from step 1 we need to have recorded the following:

(i) the regression equation [1],

(ii) the deviations mean square S^2,

(iii) $\bar{h}_1$, the mean disc meter height from all the pooled data,

(iv) $SS(h) = \Sigma(h - \bar{h}_1)^2$, and

(v) n_1 = total first stage size.

Stage 2. - The estimation stage.

Consider the question now of estimating forage availability in a specific paddock of an experiment.

(a) Choose n_2 (Usually about 40 points) at random and at each point record the disc meter height h.

(b) Calculate $\bar{h}_2$, the mean disc meter height for the paddock and S_2^2, the variance among the measured heights. Now calculate:

$$\hat{w} = a + b\,h,$$

where a and b come from equation [1].

This calculated value, $\hat{w}$, is the predicted weight of forage, per unit disc meter area, in the paddock of interest.

(c) Make the following calculation:

$$Var(\hat{w}) = S^2[1/n + (\bar{h}_1 - \bar{h}_2)^2/SS]$$
$$+\ b^2S_2^2/n_2 + S^2S_2^2/(SS.n_2) \qquad \text{---}\ [2]$$

and $SE(\hat{w}) = \sqrt{var(w)}$.

Note that these formulae do not correspond to the standard regression formulae due to the random nature of the second stage sampling.

2. Analysis of a Specific Data Set

In order to examine the efficiency of this scheme, data was collected from a mixed pasture including rye, ryegrass and crimson clover.

2.1 Basic Analysis

A total of 50 first stage units were chosen using 2 transects. In addition, 4 points were chosen where the pasture was particularly high. A regression analysis based on 10 deliberately chosen points is shown in table 1. This typifies the type of regression commonly found.

A total of 198 second stage units were sited on a rectangular grid pattern. The markedly skew frequency distribution of these heights is illustrated in figure 1.

Table 1. Regression of first stage sample

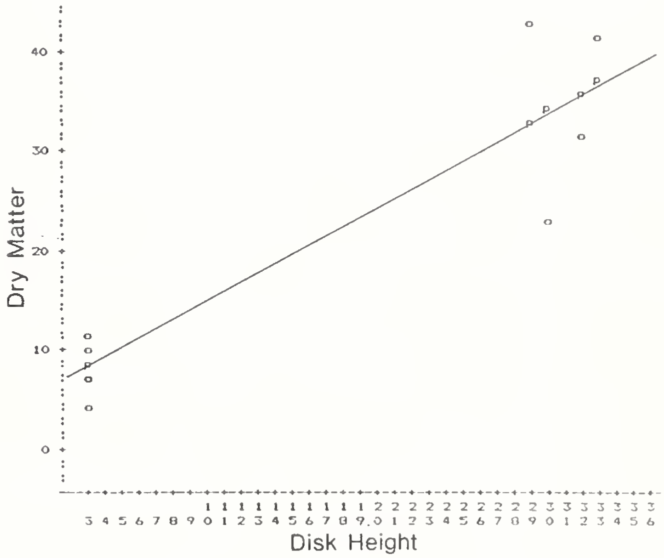
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value
Model	1	1944.94055	1944.94055	52.723
Error	8	295.12045	36.89006	
C Total	9	2240.06100		

Root MSE	6.07372	R-Square	0.8683
Dep Mean	22.17000	Adj R-Sq	0.8518
C.V.	27.39611		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0
INTERCEP	1	5.509196	2.99231734	1.841
DH	1	0.946637	0.13037213	7.[illegible]61



2.2 Analysis to examine the effects of skewness

The following two-stage simulation scheme was carried out. In stage 1 the regression parameter estimates were randomly generated so that their means corresponded with those in the observed real sample of size 10. In the second stage, a sub-sample of size 40 was randomly drawn from the real observed 198 units. Then the predicted forage value was calculated from its regression equation and its SE using equation [2]. This was repeated 1000 times and two frequency distributions were drawn up. The first is that of the predicted values w and the second is that of

$$t = (\hat{w} - \mu)/(SE(\hat{w}))$$

where μ is the mean value of w overall.

This calculated value should approximately follow the t distribution with 38 degrees of freedom. As the histograms in figure 2 show, the distributions are nearly symmetric and further analysis of the calculated t values shows that they are very close to their theoretical expectations.

2.3 Analysis to examine optimal choice of sample size

Using equation [2], one can calculate SE's of predicted values for varying values of n1 and n2. Figure 3 illustrates these values for n1 between 5 and 25 and for n2 up to 100.

Figure 1. Frequency of second stage disc heights

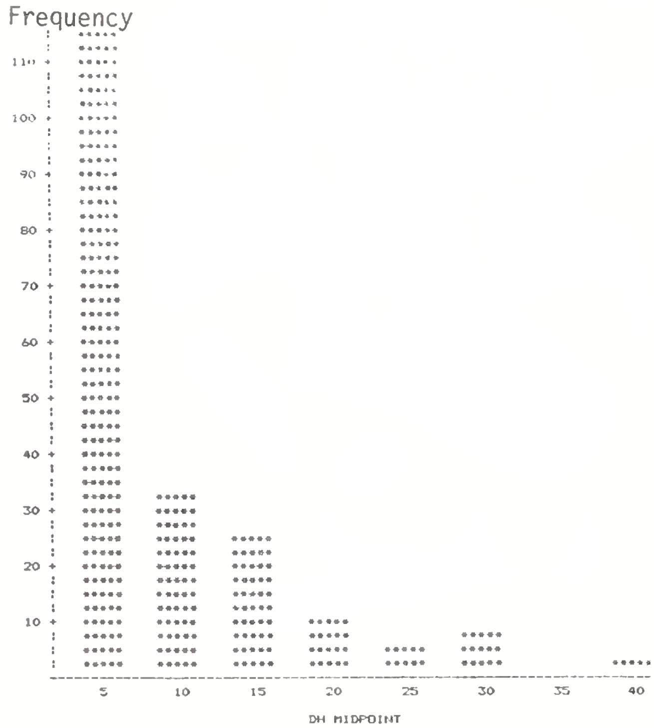


Figure 2. (a) Histogram of predicted values

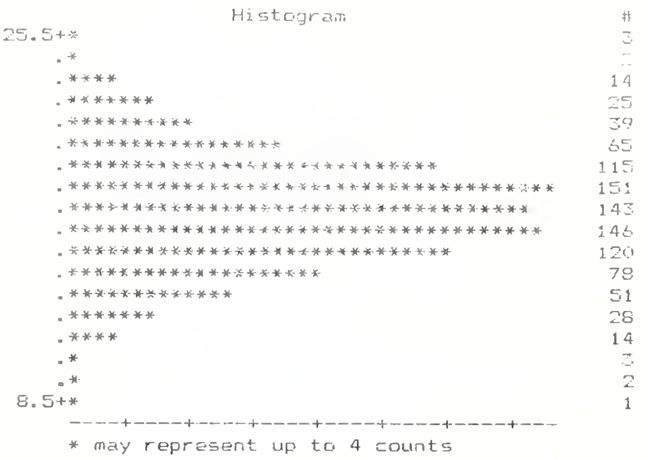


Figure 2. (b) Histogram of t values

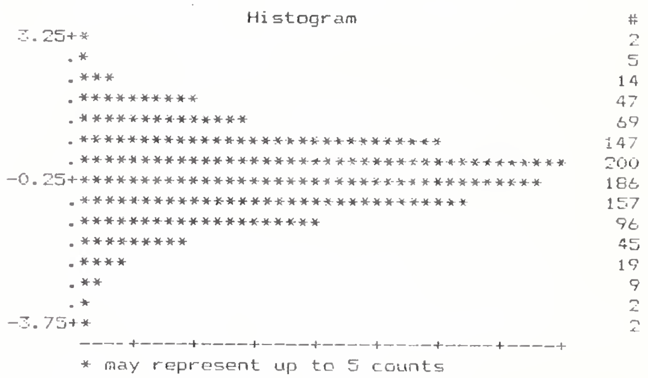
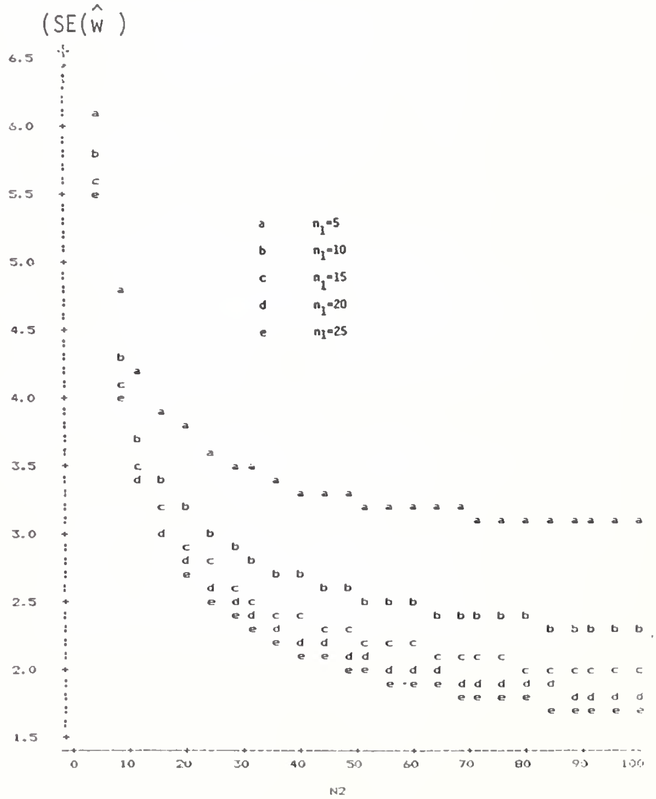


Figure 3. $(SE(\hat{w}))$ for varying sample sizes



An alternative approach is to determine an optimal sampling strategy which will minimize cost to achieve a specific accuracy. In table 2 these values are given for cost ratios, being the relative costs of first and second stage units between 2.5 to 1 and 10 to 1 (the cost being considered in terms of time required to obtain a first and second stage sample).

Table 2. Optimal sample sizes for varying cost ratios.

	Cost Ratios*							
	1:2.5		1:5		1:7.5		1:10	
SE	n_1	n_2	n_1	n_2	n_1	n_2	n_1	n_2
1.8	27	72	23	86	21	97	20	107
1.9	23	60	19	72	18	81	17	89
2.1	19	51	16	61	15	69	14	75
2.3	17	43	14	52	13	59	12	65
2.4	14	38	12	45	11	51	11	56
2.6	13	33	11	40	10	45	9	49
2.8	11	29	9	35	9	40	8	43
2.9	10	26	8	31	8	35	7	39
3.1	9	23	7	28	7	32	7	35
3.3	8	21	7	25	6	28	6	31
3.4	7	19	6	23	6	26	5	28
3.6	7	17	6	21	5	23	5	26
3.8	6	16	5	19	5	21	4	24
4.0	5	14	5	17	4	20	4	22
4.1	5	13	4	16	4	18	4	20
4.3	5	12	4	15	4	17	3	18
4.5	4	11	4	14	3	16	3	17
4.6	4	11	3	13	3	14	3	16
4.8	4	10	3	12	3	13	3	15
5.0	4	9	3	11	3	13	3	14
5.1	3	9	3	10	3	12	2	13
5.3	3	8	3	10	2	11	2	12
5.5	3	8	2	9	2	10	2	11
5.6	3	7	2	9	2	10	2	11
5.8	3	7	2	8	2	9	2	10

* Cost ratio is defined as the ratio of costs of sampling one second stage unit to one first stage unit.

Finally it is worth commenting that in the set of data used, in order to achieve the same precision using quadrat sampling only, as what we get from 10 stage 1 and 40 stage 2 units, one would need to sample 18 first stage quadrats.

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EFFECT OF ENDOPHYTE LEVEL OF TALL FESCUE ON SUBSEQUENT FEEDLOT PERFORMANCE OF STEERS[1/,2/]

N. Andy Cole[3/]

Introduction

Approximately 80% of the tall fescue (Festuca arundinacea Schreb) pastures in the Southeast and Midwest are infested with the endophytic fungus Acremonium coenophialum (Daniels et al., 1985). When consuming infested forage, cattle have lower feed intakes, poorer daily gains, and lower heat tolerance than cattle consuming uninfested forage pastures (Hemken et al., 1981; Stuedemann and Hoveland, 1988). Other clinical signs of endophyte toxicity are rough haircoats, rapid breathing, elevated body temperature, and lowered serum prolactin concentrations (Stuedemann and Hoveland, 1988). For many years, the cattle feeding industry reported that calves from areas with predominately fescue pastures had a higher incidence of health problems [especially bovine respiratory disease (BRD)] than calves from nonfescue areas. It was generally felt this high incidence of BRD was due to the small size of cattle operations and the marketing system used. In the past few years, the possible role of the fescue endophyte in this health problem has been considered.

Stuedemann et al. (1985b) reported that the adverse effects of the fescue endophyte appeared to carry over for 4-8 weeks in calves switched from high- to low-endophyte pastures. The adverse effects appeared to show up almost immediately in calves switched from low- to high-endophyte pastures. In the past few years, several trials have been conducted to determine how cattle from endophyte infested pastures perform in the feedlot and if carry-over effects cause increased health problems.

Animal Health

Diagnostic Lab Reports. No controlled data are available to indicate that a carry-over effect of the fescue endophyte causes increased incidence of health problems in feeder calves. Perino (1985) reported severe cases of heat stroke in some groups of feeder calves during the first 3-5 days in the feedlot in July. Death losses as high as 10% were reported in some lots. Heat sensitivity appeared to continue for 2-4 weeks, although all groups were not affected to the same degree. Cattle in the affected groups were known to have grazed fescue pastures prior to entering the feedlot and had typical symptoms of summer fescue toxicosis.

Sprowls (1987) reported that groups of cattle with overt signs of fescue toxicosis generally appeared to have a high incidence of respiratory disease. However, the major health problem associated with cattle from fescue pastures was heat stroke during the summer months. Other problems associated with cattle from fescue pastures were low serum selenium and serum/liver copper levels. Other studies have also reported low serum selenium (Lackey, 1985) and lowered serum and liver copper (Stoszek et al., 1979) in cattle from fescue pastures.

In four controlled studies, yearling cattle that had grazed pastures containing high (59% infested), moderate (29% infested), or low (8% infested) levels of endophyte were shipped from Georgia to Texas (Cole, 1987; Cole et al., 1987). Steers on the four trials arrived in July, August, September, and October. No animals in any group required treatment for respiratory disease; however, steers from high-endophyte pastures tended to have higher morbidity scores than steers from low-endophyte pastures, based on nasal discharge, ocular discharge, and elevated rectal temperature. Steers from high-endophyte pastures tended to have lower serum complement levels than steers from bermudagrass pastures (Purdy et al., 1987), suggesting a suppressed immune response in steers from high-endophyte pastures.

Marketing and Transit Shrink

The effects of the fescue endophyte on marketing-transport shrink of feeder steers are equivocal. Some studies have reported greater shrink in steers from highly infested pastures (Cole et al., 1987), while others have reported less shrink in calves from infested pastures (Cole et al., 1987; Lusby, 1988). If the endophyte does affect marketing-transit shrink, the results are probably dependent upon factors such as weighing conditions, the forage fed prior to loading, and weather conditions.

Performance in the Feedlot

Missouri Studies. Hancock and Williams (1985) compared the feedlot performance of steers

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1/ Contribution from USDA, Agricultural Research Service, Conservation and Production Research Laboratory, P.O. Drawer 10, Bushland, TX 79012.

2/ For presentation at the 44th Annual Meeting of the Southern Pasture and Forage Crop Improvement Conference, Lexington, KY. May 10-12, 1988.

3/ Research Animal Scientist, USDA, Agricultural Research Service, Conservation and Production Research Laboratory, Bushland, TX 79012.

from fescue, orchardgrass, and bromegrass pastures (Table 1). During the early portion of the feeding period, calves from fescue pastures tended to have the poorest performance; however, by the end of the 112-day feeding period, calves from fescue pastures had faster daily gains and more efficient feed conversions than steers from orchardgrass and bromegrass pastures.

Oklahoma Studies. In one study (Lusby, 1988), steers grazed pastures of endophyte-infested fescue, infested fescue + clover, and endophyte-free fescue for 197 days (Nov. to May 1987) (Table 2). Steers were held on ryegrass pastures for 6 days and then moved about 450 km to a feedlot for finishing. Steers from infested pastures gained about 55 kg less than the remaining two treatments during the grazing period. Weight gains were slightly higher in steers from infested pastures than in steers from endophyte-free pastures during the early portion of the feeding period and were significantly higher by the end of the feeding period. There were no effects on carcass traits.

Arkansas Studies. In a study by Piper et al. (1987), steers grazed endophyte-infested or endophyte-free fescue pastures for 84 or 168 days. Steers were moved to drylot pens in October. Steers which had grazed infested pastures had faster feedlot daily gains (Table 3). Serum prolactin concentrations were lower in steers from infested pastures on days 0 and 7 in the feedlot but were similar by day 14 in the feedlot.

In a second study (Piper et al., 1987), steers grazed infested and noninfested pastures and were moved to the feedlot in July. Daily weight gains in the feedlot were not significantly different; however, steers from infested pastures tended to have lower daily gains than steers from noninfested pastures. Serum prolactin concentrations were lower in steers from infested pastures on days 0, 7, 14, and 21 in the feedlot but were similar by day 28. The differences in performance and serum prolactin concentrations in the October and July studies suggested that the ambient conditions during the feeding period could affect the time required for calves from endophyte-infested pastures to recover from the adverse effects of the endophyte.

Kentucky Studies. Smith et al. (1986) allowed steers to graze infested or noninfested pastures from April to September, when they were moved to drylot for 59 days. Initial weights were 349 and 445 kg for the infested and noninfested groups, respectively (Table 4). Steers from endophyte-free pastures had higher feed intakes, lower daily gains, and higher feed/gain ratios than steers from high-endophyte pastures. Due to the heavy starting weights of the steers from the low-endophyte pastures, it could not be clearly determined if these effects were due solely to the endophyte or were partly due to differences in starting weights and body condition of the steers.

USDA-ARS:Georgia-Texas Studies. Four cooperative studies have been conducted between investigators at the USDA-ARS, Watkinsville, GA, and Bushland, TX. In each study, 12 steers grazed pastures containing high, moderate, or low endophyte levels. In the first two studies, all animals were of Angus breeding; and in the latter two studies, one-half were Angus and one-half were Brahman-crossbred. Steers were shipped from Georgia to Texas in October 1985, July 1986, August 1986, and September 1987. Steers were removed from pastures, fasted overnight, and weighed. After 2 days in a simulated orderbuyer barn, steers were transported for 26 hours to Texas. Upon arrival, steers were weighed, body temperature recorded, and assigned to pens equipped with Pinpointers (Model 4000B, UIS Corp., Cookville, TN) for measurement of individual feed intake. Cattle were slaughtered when backfat thickness was estimated to be 12 mm. In trials 2, 3, and 4, six steers from bermudagrass pastures were also included.

In no trial was there evidence of a significant carry-over effect of the endophyte (Table 5). In all trials, steers from high-endophyte pastures had faster daily gains and improved feed/gain ratios than steers from low-endophyte pastures during the first 28 days on feed. Carcass traits were not affected in any trial.

Serum cholesterol values were lower in steers from high-endophyte than low-endophyte pastures for about 14 days, suggesting some carry-over effect of the endophyte (Stuedemann et al., 1985a). This carry-over effect, however, did not affect early feedlot performance or health. Subjective observations indicated that in the summer trials, calves exhibited some heat stress during the afternoon. Respiration rates of steers from the high-endophyte pastures tended to be higher than those of steers from low-endophyte or bermudagrass pastures; however, all steers tended to have elevated respiration rates, even during the cool of the morning. Whether this was due to a rapid change in altitude (from about 130 m to 1,700 m), to a subclinical respiratory infection, or to other causes was not clear.

Conclusions

The available data and observations suggest that calves from fescue pastures infested with endophyte may have more health problems than calves from noninfested pastures, especially during hot weather. If they remain healthy,

calves from highly infested pastures will likely have feedlot performance equal to or better than calves from noninfested pastures. This is probably the result of compensatory gain. Differences in feedlot performance of calves from high- and low-endophyte pastures may be affected by environmental conditions (Hemken et al., 1981) and by differences in performance during the grazing period.

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TABLE 1. EFFECT OF PREVIOUS FORAGE ON FEEDLOT PERFORMANCE (HANCOCK AND WILLIAMS, 1985).

Item	Fescue	Orchardgrass	Bromegrass
Daily weight gain, kg			
Days 0-28	0.81	0.91	1.00
Days 0-112	1.38	1.29	1.25
Dry matter intake, kg/hd/d			
Days 0-28	7.2	7.3	7.4
Days 0-112	8.5	8.5	8.6
Feed/gain ratio			
Days 0-28	9.68	10.21	7.93
Days 0-112	6.60	6.90	7.06

TABLE 2. FEEDLOT PERFORMANCE OF STEERS FROM ENDOPHYTE-INFESTED AND ENDOPHYTE-FREE FESCUE PASTURE IN OKLAHOMA (LUSBY, 1988).

Item	Infested	Infested + clover	Endophyte-free
No. steers	27	19	26
Weight off pasture, kg	343^{a}	399^{b}	398^{b}
Weight gains 6 days on ryegrass	17.3^{a}	17.7^{a}	5.9^{b}
Shipping shrink, kg	13.6	21.8	16.8
Daily gains in feedlot, kg			
Days 0 - 49	2.20^{a}	1.96^{b}	2.10^{ab}
Days 0 - 117	1.79	1.72	1.73
Ship to 117	1.66^{a}	1.52^{b}	1.57^{b}

a,b Means without a common superscript differ ($P < .05$).

TABLE 3. INFLUENCE OF GRAZING ENDOPHYTE-INFESTED OR ENDOPHYTE-FREE FESCUE ON FEEDLOT PERFORMANCE OF STEERS STARTED ON FEED IN JULY OR OCTOBER IN ARKANSAS (PIPER ET AL., 1987).

Item	Infested	Endophyte-free
Trial 1 - October		
Weight gain on pastures, kg	27^{a}	38^{b}
Feedlot daily gain, kg	1.26^{a}	1.05^{b}
Serum prolactin day 0, ng/ml	8	22
Trial 2 - July		
Feedlot daily gain, kg	0.91	1.00
Serum prolactin day 0, ng/ml	80	137

TABLE 4. FIFTY-SIX-DAY FEEDLOT PERFORMANCE OF STEERS FROM ENDOPHYTE-INFESTED AND ENDOPHYTE-FREE PASTURES IN KENTUCKY (SMITH ET AL., 1986).

Item	Infested	Endophyte-free
Pasture daily gains, kg	0.49	0.93
Feedlot starting wt., kg	349	445
Initial rectal temp., C	41.0^{a}	39.9^{b}
Dry matter intake, kg	7.71	8.83
Daily gain, kg	1.18	1.09
Feed/gain ratio	6.6^{a}	8.1^{b}

TABLE 5. FEEDLOT PERFORMANCE OF ANGUS STEERS FROM LOW-, MODERATE-, OR HIGH-ENDOPHYTE PASTURES SHIPPED FROM GEORGIA TO TEXAS (COLE ET AL., 1987).

Item	Low-fungus	Moderate-fungus	High-fungus
Trial 1 (October 1985)			
Weight off pasture, kg	333^{a}	312^{b}	283^{c}
Daily gain, kg			
Days 0-28	0.66	0.98	1.05
Days 0-finish	1.41^{a}	1.38^{a}	1.68^{b}
Feed/gain ratio			
Days 0-28	11.76^{a}	7.35^{b}	6.94^{b}
Days 0-finish	6.49^{a}	6.45^{a}	5.46^{b}
Trial 2 (July 1986)			
Weight off pasture, kg	285^{a}	276^{a}	257^{b}
Daily gain, kg			
Days 0-28	1.86	2.14	2.18
Days 0-finish	1.68	1.78	1.85
Feed/gain ratio			
Days 0-28	4.54^{a}	3.79^{ab}	3.36^{b}
Days 0-finish	5.78	5.46	5.32
Trial 3 (August 1986)			
Weight off pasture, kg	321	310	302
Daily gain, kg			
Days 0-28	1.89	2.54	2.81
Days 0-finish	1.86^{a}	1.60^{b}	1.73^{ab}
Feed/gain ratio			
Days 0-28	3.73	2.65	2.42
Days 0-finish	5.85	6.17	5.95
Trial 4 (September 1987)			
Weight off pasture, kg	334	317	294
Daily gain, kg			
Days $0\text{-}28^{d}$	1.08	1.61	2.02
Days 0-finish^{d}	1.50	1.80	1.92
Feed/gain ratio			
Days $0\text{-}28^{d}$	6.94	5.58	4.57
Days 0-finish^{d}	6.25	5.75	5.35

^{a,b,c} $P < .05$.

^{d} Linear effect ($P < .05$).

FORAGE MANAGEMENT IN AN INTEGRATED BEEF-FORAGE SYSTEM IN ARKANSAS, A TOTAL FARM MANAGEMENT APPROACH

B. J. Hankins[1]

INTRODUCTION

The major objective of the Arkansas beef-forage management project is to assemble an integrated set of forage and beef cattle management practices on a typical beef farm in Arkansas and to test the hypothesis that adoption of such a set of Extension recommendations would increase profitability in a beef cattle enterprise. The project began in 1984 and will continue through 1989.

A 425-acre farm in Northwest Arkansas was chosen for the project. Nine University of Arkansas Extension and Research faculty members, Mr. Charles Moreton who owns the farm, and Mr. Mike Hamilton and Mr. Merle Gross, local county Extension agents, comprise the committee that annually supervises the project. They represent expertise in the areas of soils, forages, animal sciences, agricultural engineering, weeds, and entomology.

The Moreton farm is comprised of the homestead of 285 acres and a second 173-acre farm located four miles away. In 1984, each of the 18 fields on the farm were numbered for record keeping and a detailed inventory taken of soils, vegetative cover, animals, machinery, fencing, hay storage facilities, and water availability. Bermudagrass was found to be the dominant tame forage species on only 10 acres of the farm's 386 acres of pasture land. Tall fescue with a 60 to 100 percent endophyte infection level predominated on the remaining 376 acres. The inventory also showed that soils were fertile with a slightly acid pH. This was the result of 15 years or more of continuous poultry litter use for fertilizer. Ninety-two percent of the acreage had an available phosphorus level above 120 pounds per acre. Sixty-eight percent of the acreage had an available potash level above 200 pounds per acre. Seventy-three percent of the acreage had pH values of greater than 6.5.

Mr. Moreton began managing the farm upon the death of his father-in-law at about the time this project began. At that time, it supported 228 crossbred cows, 94 calves, and 15 bulls. Cattle typically showed summer syndrome symptoms, and the average 205-day adjusted calf weaning weight was 283 pounds.

ACCOMPLISHMENTS

Three major forage-related goals were chosen at the beginning of the project. They were: (1) to improve hay quality, (2) to increase the acreage of warm season forage, and (3) to upgrade the cool season forage.

Hay

Hay quality was improved by using more timely harvests and by converting from low to high quality forage species. Crude protein content in large round bales was increased as much as six and TDN as much as eight percentage points since 1984. Hay in 1986 tested 11 percent crude protein and 55.7 percent TDN. Further improvement in quality and a reduction in dry matter loss are anticipated as new hay storage facilities are constructed in 1988.

Increasing Warm Season Acreage

In Northwest Arkansas, warm season forage species should predominate on one-third of the acreage of beef cattle farms. Bermudagrass predominated on less than three percent of the pasture acreage of the Moreton farm in 1984. In 1987 it comprised 23 percent. The conversion from cool to warm season forage species (tall fescue to bermudagrass) was accomplished by two methods.

Forty-five acres of tall fescue-common bermudagrass mixture were converted to acres dominated by common bermudagrass in a two-year project by annually discriminating against tall fescue and favoring bermudagrass. This was done with herbicide applications in late March followed by a fertilizer treatment in late June. In 1985 the herbicide treatment was two pounds of Atrazine per acre; in 1986 it was one pound of Atrazine mixed with one pint of Paraquat per acre. In 1985 the fertilizer treatment was 1,500 gallons of liquid hen litter per acre; in 1986 it was 100 pounds of 34-0-0 plus 100 pounds of 0-0-60 commercial fertilizers plus 2,600 gallons of liquid hen litter per acre. The out-of-pocket cost for these materials and their applications was $21.76 per acre in 1985 and $38.70 in 1986.

Hybrid bermudagrass establishment was accomplished in 1985-86 on 20 acres of field 8 by first fall plowing to kill fescue. Wheat was planted at an expense of $31.64 per acre. Forage valued at $35.55 per acre was grazed by replacement heifers from the wheat during winter and spring. Then the wheat stubble was plowed and Midland bermudagrass sprigged in May of 1985 at a cost of $61.50 per acre.

Upgrading Tall Fescue

Renovation of 97 acres of endophyte-infected fescue has been accomplished on five fields by either (1) grazing close, then overseeding

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with a mixture of red and white clover, (2) killing the fescue and reseeding with endophyte-free fescue and clover, or (3) killing the fescue and reseeding with orchardgrass and clover. A no-till drill was used to plant the new forage species into dead sod without conventional seedbed preparation.

A summary of the practices used for each field is abridged in Table 1 below. The remaining unrenovated acreage of endophyte-infected tall fescue on the farm (169 acres) has been fertilized according to soil test recommendations and harvested for hay and/or grazed rotationally in accordance with approved Extension recommendations.

Table 1. Major Practices and Materials Used to Renovate Endophyte-Infected Tall Fescue Pastures

Field Number and Acres	Original Forage Cover	Dominant Forage Cover After Renovation	Major Materials and Practices Used in Pasture Renovation/A	Out-of-Pocket Costs Per Acre ($)	Date Accomplished
11 17 acres	100% KY31 fescue and weeds	50% Forager fescue 40% clover 10% other	1. 1 qt. Roundup 2. 15 lbs. Forager fescue 3. 8 lbs. Kenland red clover 4. 2 lbs. Regal Ladino clover 5. $4.00/A drill rental 6. $6.29/A interest	63.47	Fall 1984
3A 13 acres	100% KY31 fescue and weeds	Same as before + 15% clover	1. Grazed to 2" stubble height 2. 8 lbs. Redland II red clover 3. 2 lbs. Regal Ladino clover 4. $4.00/A drill rental 5. $2.30/A interest	25.62	Fall 1984
3B 20 acres	100% KY31 fescue and weeds	Same as before + 20% clover	1. Grazed to 2" stubble height 2. 1.5 T/A lime 3. 8 lbs. Redland II red clover 4. 2 lbs. Regal Ladino clover 5. $4.00/A drill charge 6. $3.77/A interest	41.83 1/	Fall 1984
7 30 acres	100% KY31 fescue and weeds	100% new fescue varieties	1. 1 pint Embark/A (1985) 2. 2 one pint applications of Paraquat 3. 9 varieties of tall fescue 4. $4.00/A drill rental 5. $3.90/A interest	42.90 2/	Fall 1986
12A 17 acres	100% KY31 fescue and weeds	70% orchard-grass 20% clover 10% other	1. 1 pint Embark/A (1986) 2. 2 applications of 1½ pt. Gramoxone/A 3. 2T lime/A 4. 10 lb. orchardgrass/A 5. 6 lbs. red clover/A 6. $4.00/A drill charge 7. $7.15/A interest charge	78.65 3/	Fall 1987

1/ Lime charge was not amortized.
2/ Not included are 200 lbs./A 34-0-0, hay harvest, 100 lbs. wheat seed, 3 lbs. arrowleaf clover seed, and drill rental for overseeding wheat grown in 1985-86 and 225 lbs./A 34-0-0, and 1 pt. Weedmaster/A in 1986.
3/ Lime charge was not amortized.

SUMMARY OF RESULTS

A total economic analysis that includes fixed costs has not been run on any of the renovated fields. However, accurate records of major variable costs were kept as were hay yields and the number of days grazing for each field. A summary of these results is shown as comparisons for three fields in Table 2.

During the first two years of this project, 65 cows were culled and 55 replacement heifers purchased; the average cow weight increased by 101 pounds; the calf crop was increased from 75 to 91 percent (based on cows retained in the herd); the calf weaning weight was increased by about 100 pounds; and returns above specified costs increased by almost $15,000.00 per year.

Table 2. Comparative Annual Returns From Three Pastures

Field Number	Size (Acres)	Current Forage Species	Net Out-of-Pocket Returns/A 1986	1987 Field Fertilization Program	1987 Net Out-of-Pocket Returns
3A	12	KY31 Tall Fescue Plus Clover	$11.78	200 lbs. 34-0-0/A	$19.31
8A&B	20	Midland Bermudagrass	$86.50	400 lbs. 34-0-0 0.7 loads poultry litter/A	$82.60
11	17	Forager Tall Fescue and Clover	$82.60	200 lbs. 0-0-60/A	$73.97

CONCLUSION

Net profits are likely to be substantially increased when an integrated system of forage and livestock management practices are incorporated into a beef cattle enterprise. This project lends credence to management practices developed by University research and recommended by the Cooperative Extension Service.

GENERAL BUSINESS AND INFORMATION EXCHANGE GROUP MEETINGS

MINUTES OF BUSINESS MEETING
44th SPFCIC
May 12, 1988
Lexington, Kentucky

Dr. Don Ball, Chairman, called the meeting to order and requested a roll-call of states.

Old Business

1. The secretary's report was presented but not read because it had been published in proceedings of the 43rd conference.

2. The treasurer's report was accepted as read, which indicated a balance of $6,162.77. Motion by Jim Kaiser and seconded by Jim Rice. Report attached.

3. A comment by J. P. Mueller about the current balance indicating a need for evaluating whether we were within IRS guidelines. Don Ball appointed a committee of J. Matches (chair), Bill Stringer and J. Green to make recommendations at the 45th conference about the "surplus" balance.

New Business

1. B. J. Hankins (Arkansas) reminded the group that we would meet in Little Rock in early June 1989. He announced he is seeking program and tour ideas. A preliminary indication was that a one-half day tour is desired.

2. Mark Hussy of Texas read an invitation from Dr. Clark, Research Director TAM, to meet in Texas in 1990. Motion to accept by J. D. Burns and seconded by J. P. Mueller. Motion passed.

3. H. Lippke, chair of nominating committee, recommended Ken Quesenberry, as chairman-elect-elect. Motion by J. D. Burns that he be elected by acclamation. Seconded by W. McMurphy. Motion passed.

4. W. Essig, chair of resolution committee, read the resolution expressing gratitude to Kentucky host and all conference workers. See attached. Motion by Essig to send resolution to appropriate UK administration. Second by W. McMurphy. Motion passed.

5. Other activities included passing of gavel by Don Ball to Werner Essig and the presentation cf plaque to Don Ball by H. Lippke.

6.The meeting was adjourned.

Respectfully Submitted,

James T. Green
Secretary/Treasurer

MINUTES OF EXECUTIVE COMMITTEE
44th SPFCIC
May 10, 1988
Lexington, Kentucky

People Present: H. Lippke, D. Ball, J. Mosjidis, R. Kalmbacher, T. Johnson, J. Stuedemann, L. Sollenberger, J. Green, W. Essig

Discussion Topics:

1. Don Ball requested that the names of elected officers for the work groups be obtained and shared soon after this conference.

2. Don Ball mentioned that D. Belesky had agreed to continue serving as Proceedings Coordinator and would obtain a new bulk mail permit for Beckley, WV.

3. Don Ball will appoint a committee to evaluate what to do with the money that is presently in the account. This decision was brought about by the fact that the account has over $6,000 and there is a need to keep this at a somewhat lesser balance.

4. Ball named the nominating committee consisting of W. Faw, C. Dougherty, H. Lippke. They are to select a nominee for Chairman Elect-Elect of SPFCIC.

5. Ball appointed W. Essig, J. Stuedemann, and B. Nelson to the resolution committee.

6. There was some discussion about making sure that complete programs were mailed in advance of the meeting. Don Ball will take the suggested timetable assembled by H. Lippke and develop an official outline of responsibilities and calendar of actions to be followed by future officers. There is a need for better coordination among work group program chairmen, the SPFCIC program chairman and local arrangement chairman.

RESOLUTION ADOPTED UNANIMOUSLY BY THE 44TH ANNUAL SOUTHERN PASTURE AND FORAGE CROP IMPROVEMENT CONFERENCE

WHEREAS, the membership of the 44th annual Southern Pasture and Forage Crop Improvement Conference has reaped great benefits from its participation in the Conference, and
WHEREAS, such benefits could not have been attained without the warm, friendly, hospitable and concerted efforts of the staff and administration of the University of Kentucky;

BE IT RESOLVED: That this 44th Conference express its grateful appreciation to the staff of the University of Kentucky for the warm, friendly welcome extended to it and the use of the superior facilities provided during the meeting in the Radisson Plaza Hotel in Lexington and the field trip to Spindletop Farm;

That the University of Kentucky and its personnel are to be commended for their awareness of agricultural problems, particularly in Grassland agriculture, and for their leadership and vision in attacking and solving the problems in improvement, management, and utilization of forage crops as we move toward the challenges of the future;

That special recognition is extended to Dr. Jack Hiatt, Chairman, Department of Agronomy, Dr. Virgil Hays, Chairman, Department of Animal Science, and all individuals serving on the Local Arrangements Committee and commercial firms for making our stay in Kentucky so pleasant.

That special recognition is due and extended to Conference Arrangements Chairman Dr. Norm Taylor, Conference Chairman Dr. Don Ball, Past Chairman and Program Chairman Hagen Lippke, and to our esteemed and faithful Secretary/Treasurer, Jim Green.

THEREFORE, We move that this resolution be adopted by unanimous acclamation and recorded in the Minutes; and further, that a copy of this resolution be sent to:

Dr. David Rosell, President, University of Kentucky
Dr. C. E. Barnhart, Dean, U.K. College of Agriculture
Dr. Milt Shuffot, Associate Dean for Research
Dr. Shirley Phillips, Associate Dean for Extension

H. W. Essig
John Stuedemann
Billy Nelson

SOUTHERN PASTURE AND FORAGE. CROP IMPROVEMENT CONFERENCE EXECUTIVE COMMITTEE 1989

Executive Officers

Warner Essig	Chairman
Rob Kalmbacher	Chairman-elect
Kenneth Quesenberry	Chairman-elect-elect
Don Ball	Immediate Past Chairman and Program Chairman for 1989 (45th Meeting)
Jim Green	Secretary-Treasurer
David Baltensperger	Breeders Work Group Chairman
Lynn Sollenberger	Ecology-Pnysiology Work Group Chairman
Bruce Pinkerton	Extension Work Group Chairman
Lance Tharel	Utilization Work Group Chairman
Dave Belesky	Proceedings Coordinator

Officers of 1989 Work Groups

Breeders Work Group

David Baltensperger	Chairman Secretary
Jorge Mosjidis	Past Chairman and Program Director

Ecology and Physiology Work Group

Lynn Sollenberger	Chairman
Richard Joost	Chairman-elect
Chuck West	Secretary
Vivian Allen	Past Chairman and Program Director

Extension Work Group

Bruce Pinkerton	Chairman
B. J. Hankins	Secretary and Program Director
Troy Johnson	Past Chairman

Utilization Work Group

Lance Tharel	Chairman and Program Director
Steve Schmidt	Chairman-elect Secretary-elect
John Stuedemann	Past Chairman

SPFCIC
Breeders Work Group, May 11, 1988

Meeting called to order by Jorge Mosjidis 11:30 a.m.

Minutes approved

No Old Business

Nomination of Mark Hussey as Secretary
- Elected by acclamation
- D. Baltensperger moves to Chairman
- J. Mosjidis moves to Program Coordinator

Dr. Everett Emino, Administrative Advisor, announce need for renewal of Regional Information Exchange Groups by 1990.

Dr. J. Preston Jones, our CSRS representative, said Bob Conger did renewal last time.

Meeting was adjourned.

Secretary,
D. D. Baltensperger

cc: Director of Exp. Sta. Kentucky
Administrative Advisor - Dr. Emino
CSRS Rep. - Dr. J. P. Jones

ECOLOGY AND PHYSIOLOGY WORK GROUP
BUSINESS MEETING

The meeting was called to order by Dr. Lynn Sollenberger at 12 noon on 5/11/88. Dr. Sollenberger announced the current officers of the group: Dr. Vivian Allen (VPI, Program Chair for the Lexington meeting), Dr. Lynn Sollenberger (Univ. of Florida, Chair), and Dr. Richard Joost (LSU, Secretary). The chair then opened the floor for nominations for secretary of the group for 1988-89. Chuck West (Univ. of Arkansas) nominated Wilfred McMurphy (OSU). The motion was seconded by Rob Kalmbacher (Univ. of Florida). Wilfred McMurphy nominated Chuck West, indicating that the idea was to get younger scientists involved in the administration of the organization. The motion was seconded by Rich Joost. Chuck West was elected by a majority vote.

Dr. Sollenberger then requested suggestions from the floor regarding topics for next year's meeting. The following suggestions were offered:

1. Overview of soil fertility/plant nutrition as it relates to soil/plant/animal mineral utilization.

2. Forage components acting as feeding stimulants and feeding deterents.

3. Possibility of discussing the present state of modeling including coverage of expert systems approaches.

4. Coverage of the tall fescue endophyte from the perspective of our current knowledge of the toxins produced and management considerations for endophyte + and - stands. This could include the basic physiology and ecology of the endophyte/plant association.

Joe Burns (NCSU) made the suggestion that we not spend our entire time on modeling. There was general agreement with this comment. Joe Fontenot (VPI) indicated that the tall fescue/endophyte association would be a good topic for a joint meeting with the Forage Utilization Work Group. Dr. Sollenberger informed the group that they could submit any further ideas by mail to himself or Dr. Joost at any time.

There was no additional new business. Dr. Chuck West moved that the meeting be adjourned. Dale Wolf (VPI) seconded and the meeting was adjourned at 12:30.

MINUTES OF THE SPFCIC
FORAGE UTILIZATION WORK GROUP BUSINESS MEETING

Lexington, KY
May 11, 1988

The meeting was called to order by President John Stuedemann at Lexington, KY on May 11, 1988. Current officers of the Forage Utilization Work Group were introduced and individuals in attendance introduced themselves, stating their location and area of research or interest. A questionnaire was distributed asking for suggestions for program topics for future meetings.

A motion was made and seconded to dispense with the reading of the minutes of the 1987 business meeting held in Clemson, SC. The minutes were approved as printed in the proceedings of the 43rd SPFCIC. The nominating committee chaired by Lance Tharel presented Dwight Fisher, Crop Science Department, North Carolina State University as Secretary-Elect. He was unanimously elected. Lance Tharel will serve as president for the next year.

Nick Hill noted that a change in the manuscript format for the proceedings needs to be considered. The photo-ready copy sheets that have been used in the past do not work with many of the new word processors and printers. John Stuedemann agreed to bring this up with the executive committee.

The motion was made and seconded to adjourn.

The following is a summary of responses to the questionnaire on program topics:

1. Establishment/renovation of endophyte-free fescue pastures, i.e. methods- advantages and disadvantages of each.

2. Management of newly established endophyte-free fescue pastures, i.e. stocking rate and grazing pressure.

3. Should fescue (noninfected or infected) be planted separately or in combination with other perennials? (i.e. bermudagrass.)

4. Use of pasture probe or pasture meter for prediction of DM/Ac, and use of these data in management systems.

5. Methods/markers of measuring intake on warm and cool season forages, implications, new techniques on horizon.

6. Comparison of newer techniques for measuring short-term intake, i.e. bite count, bolus size measurements vs. electronic measurement or bolus movement-bolus size techniques.

7. Ammoniated hay toxicity update, i.e. causes, symptoms, prevention.

8. Research of problems associated with feeding ammoniated hay, i.e. storage, risks, are risks sufficient to warrant not advocating the practice - legal aspects (liability).

9. Endophyte relationships in tall fescue, i.e. insect, disease and drought tolerance.

10. Update: of latent information of toxins or chemicals found in tall fescue and their plant/animal relationships.

11. Forage availability x animal performance.

12. Use of microcomputers and associated software to aid in analysis of forage utilization data.

13. New techniques/ideas of data recording and handling data.

14. Use of available forage as a covariate in grazing research analysis - is this the best term? - Why? - What other options available?

Stephen P. Schmidt
Secretary, 1988

EXTENSION WORK GROUP MINUTES

The meeting of SPFCIC Extension Work Group met Wednesday, May 11, 1988 in Lexington, Kentucky. The meeting was called to order by Troy Johnson.

Those in attendance were:

Keith Edmisten, Mississippi
Jim Woodruss, South Carolina
Jim Green, North Carolina
Wade F. Faw, Louisiana
Harlan E. White, Virginia
Don Ball, Alabama
Troy Johnson, Georgia
B. J. Hankins, Arkansas
Joe Burns, Tennessee
Monroe Rasnake, Kentucky
J. Paul Mueller, North Carolina
Warren Thompson, Kentucky
Garry Lacefield, Kentucky

Dr. Johnson reported that as a result of illness, Dr. Bruce Pinkerton (Program Chairman) was unable to attend.

Chairman Johnson presented a slate of officers for 1989 including: B. J. Hankins, Secretary; Garry Lacefield, Program Chairman; and Bruce Pinkerton, Chairman. Motion by Paul Mueller, second by Wade Faw, "that officers be elected by acclimation". Motion carried.

Chairman Johnson led discussion on role, need and direction of Extension Work Group. Those in attendance agreed that the Extension Work Group had provided an important and unique opportunity for Extension Forage Workers over the years. A strong desire was expressed by those in attendance to continue the work group with options for joint session as needed. Work Group members pledged support in assisting Program Chairman and encouraged greater participation in getting materials into Proceedings.

Motion by Monroe Rasnake, second by Don Ball that "secretary and program chairman position be combined and that position be occupied by representative from host state". Motion carried.

Meeting adjourned at 9:10.

Respectively submitted,

Garry Lacefield
Secretary

SOUTHERN PASTURE AND FORAGE CROP IMPROVEMENT CONFERENCE
1988 Financial Statement

	Income	Expense	Balance
04/04/87 Balance on hand at Wachovia Bank and Trust Account #6261 206760			3,738.27
08/05/87 Deposit of balance from 43rd meeting in South Carolina	2,167.71		
04/06/88 Interest on bank account for 04/87-04/06/88	285.90		
04/28/88 Plaque for Chairman (Tro Craft Studios)		29.11	
05/04/88 Balance on Hand			$6,162.77

Respectfully submitted by James T. Green, Jr.

44th SPFCIC REGISTRANTS

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